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THE INSTITUTE OF PHYSICS

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The inclusion of particulars of a vacancy must not be taken to imply that the Institute necessarily approves of the terms offered or that might be offered. Candidates should satisfy themselves that these are satisfactory, and they may always refer to the Institute for advice.

RESEARCH INSTITUTE (ANIMAL VIRUS DISEASES), PIRBRIGHT, SURREY, invites applications for a post in the Biophysics Department at the Institute. Problems undertaken include studies on the structure of viruses, on virus-antibody interaction and on physical problems relating to dissemination of viruses. The successful applicant would be expected to work in these fields. Qualifications required: Honours degree—physics with some postgraduate experience, preferably relating to biological application. Appointment in Scientific Officer Grade (£615–£1,120) or Senior Scientific Officer Grade (£1,166–£1,420) depending on age, experience and qualifications. House available for married candidate. Superannuation under F.S.S.U. Applications to the Secretary by March 21, 1960.)

THE
UNIVERSITY OF SHEFFIELD
DEPARTMENT OF PHYSICS

Applications are invited for a RESEARCH POST in the Radioastronomy Group. The successful candidate will be expected to participate in an expanding program of research in upper atmospheric physics, including investigations of meteors, aurorae and solar-terrestrial relations. Appointment for three years in the first instance; salary range £900 × £50–£1,000 with F.S.S.U. benefits. Applications to Dr. T. R. Kaiser, Department of Physics, The University, Sheffield, 10.

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Principal: C. Chew, M.Sc.Tech., F.R.I.C.
DEPARTMENT OF
ELECTRICAL ENGINEERING
AND PHYSICS

Applications are invited for the post of LECTURER (man or woman) to teach pure and applied physics to London general degree and Grad.Inst.P. levels. Applicants should possess a good degree or equivalent qualification in the subject and have had previous teaching experience. Research facilities are available. Salary will be in accordance with the Burnham Technical Scale for lecturers as follows:—Man–£1,370–£35–£1,550. Woman — £1,100–£28–£1,240, plus equal pay instalments. Further particulars and forms of application, to be returned by March 25, 1960, may be obtained by sending a stamped addressed foolscap envelope to the Principal of the College.

SCIENCE TEACHER required September, Girls' Independent Public Boarding School. New Burnham Scale, Government Superannuation. Write fully, Headmistress, Hollington Park School, St. Leonards-on-Sea, Sussex.

GRADUATE (PHYSICS OR ENGINEERING) required to lead a development team on problems associated with the design and manufacture of discharge lamps. Opportunity for man under 30, ready to take responsibility and with aptitude for working with Research and Production groups. Ability to assess the value of new techniques or theories in this field and to develop ways of incorporating these in lamps produced by highly mechanized production process is essential. The appointment would be initially in the Development Laboratory at Shaw, Lancashire, and applications should be sent to Senior Personnel Officer, Osram Lamp Division, G.E.C. Estate, East Lane, North Wembley, Middlesex.

PHYSICIST required to undertake work on the use of electric arcs in industrial applications. This vacancy is essentially an opening for a well qualified young graduate interested in both the basic properties of arcs and in their commercial application in novel ways. Please write to The Secretary, British Oxygen Research and Development Ltd., Deer Park Road, London, S.W.19.

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IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY
DEPARTMENT OF
CHEMICAL ENGINEERING

Applications are invited for graduate and post-doctorate research stipends in the following fields :—(i) Structural and electrical studies on graphite and its crystal compounds ; (ii) Studies of thermal transformations of inorganic salts, including melting ; (iii) Structural and electrical studies on non-stoichiometric inorganic oxides. Specialized X-ray methods may be involved in each of the above. Where appropriate the work may lead to a higher degree. Apply with details of degree and any previous experience to Professor A. R. Ubbelohde, F.R.S.

THE COLLEGE OF AERONAUTICS

Applications are invited for a RESEARCH FELLOWSHIP in metallurgy or metal physics in the Department of Materials. Candidates must be university graduates with a good research background, and should preferably have a higher degree in some branch of metallurgy or solid state physics, or be intending to work for one. Publication is encouraged and the choice of research is wide. Salary in the ranges : Senior Research Fellow £1,100 to £1,350 ; Research Fellow £750 to £1,000 per annum, with superannuation under F.S.S.U. and family allowance. Appointment will be made initially for three years with prospects of continuation. Applications containing full particulars and quoting the names of three referees, should be addressed to the Recorder, The College of Aeronautics, Cranfield, Bletchley, Bucks.

Central Electricity Generating Board

Research and Development Department

Research Laboratories, Leatherhead, Surrey

HEAT TRANSFER RESEARCH

HEAT TRANSFER AND FLUID FLOW SECTION

PHYSICISTS AND ENGINEERS **Ref. PB/31**

Are invited to apply for the following vacancies :

(*a*) **GROUP LEADER**

To take charge of heat transfer work on nuclear fuel elements. The successful candidate will be required to initiate and supervise research work, much of which will be of a fundamental nature, in the fuel elements for both present and advanced types of reactor. Applicants should have a First or Second Class Honours degree, and research experience in heat transfer and fluid dynamics, or closely allied fields.

(*b*) **PHYSICISTS and ENGINEERS**

To work as members of the Heat Transfer Group mentioned above. Applicants should have an Honours degree, and research experience, in this type of work will be an advantage, although new qualified Graduates with an interest in the subject will be considered, and if appointed will be given appropriate training.

Salaries will be on scales within the following ranges according to duties and responsibilities : Post (*a*) **£1,530 – £1,985 p.a., Post** (*b*) **£1,195 – £1,775 p.a. or, up to £1,300 p.a.**

SOLID STATE PHYSICS SECTION

SOLID STATE PHYSICISTS **Ref. PB/71**

Are required for appointments at various levels in this newly formed section.

The section will be required to keep abreast, in a general way, of current technological and theoretical developments concerned with the electrical and electronic properties of non-metallic materials and to work on selected topics in this field. Individual research is encouraged ; excellent supporting facilities are available ; and emphasis is placed on fundamental aspects rather than on device development.

THE HEAD OF SECTION must hold a good honours degree and must be able to provide evidence of both theoretical and experimental ability. He will be required to take an active part in the formulation of a research programme and in the further recruitment of staff.

Salary within the range £2,160 – £2,960 p.a., according to duties and responsibilities.

SUPPORTING STAFF with similar academic qualifications are also required and students having an interest in this subject, who expect to graduate this year, are invited to apply.

Salaries on scales within one of the following ranges according to duties and responsibilities : £1,530 – £1,985 p.a., £1,195 – £1,775 p.a., and £570 – £1,300 p.a.

Where necessary, consideration may be given for financial assistance towards house purchase.

Applications stating age, qualifications, experience, present position and salary to the Personnel Officer, 24/30 Holborn, London, E.C.1, as soon as possible. Envelopes should be marked " Confidential " quoting relevant reference numbers.

UNIVERSITY OF CAPE TOWN

DEPARTMENT OF APPLIED MATHEMATICS AND THEORETICAL PHYSICS

Applications are invited for a SENIOR LECTURESHIP in theoretical physics. The successful candidate will be placed at an appropriate notch of the salary scale, £1,760 × £60 – £2,060. The senior lecturer will be concerned primarily with the teaching of advanced courses and will be expected to carry out research work in some branch of theoretical, nuclear or plasma physics. Applications (with copies of three testimonials) should state age, qualifications, teaching and research experience, and give the names of two referees whom the University may consult. Two copies of the application must reach the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1 (from whom memoranda giving the general conditions of appointment and information concerning the department and duties should be obtained) not later than March 31, 1960. A third copy must be sent direct by airmail to the Registrar, University of Cape Town, Private Bag, Rondebosch, Cape Town, South Africa, by the same date. The University reserves the right to appoint a person other than one of the applicants or to make no appointment.

UNIVERSITY COLLEGE OF GHANA

Applications are invited for (A) ASSISTANT LECTURESHIP or (B) LECTURESHIP IN PHYSICS ; candidates with interest in geophysics preferred. Salary scale : (A) £G900 ; £G950 p.a., (B) £G1,000 × £50 – £1,350 × £75 – £G1,800 ; £G1,850 p.a. Entry point according to qualifications and experience. F.S.S.U. Outfit and family allowances. Passages for appointee and family on appointment, leave and normal termination. Part-furnished accommodation at a charge not exceeding 7·5% of salary. Detailed applications (6 copies) naming 3 referees by March 24, 1960, to Secretary, Inter-University Council for Higher Education Overseas, 29 Woburn Square, London, W.C.1, from whom further particulars may be obtained.

SENIOR PHYSICIST

Smith & Nephew Research Ltd. invite applications for the position of Senior Physicist to lead a small team investigating the fundamental rheological properties of pressure sensitive adhesives. The successful applicant will have an Honours Degree in physics with an interest and experience in properties of matter. He will command a salary of not less than £1,300 per annum. There is a Contributory Pension Scheme and working conditions are in conformity with modern practice in industry. The Laboratories are located in a country district 25 miles north of London. Write, giving full details, to : Research Manager (Administration), Smith & Nephew Research Ltd., Hunsdon Laboratories, Ware, Herts.

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SENIOR PHYSICIST

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A good honours degree in physics and research experience is required for the position, which calls for a keen interest in classical physics. Previous experience in the paper field is not essential. The successful applicant will be between 30 and 45 and of proven ability in research. Salary and prospects will be excellent, with the added stimulus of playing a leading role in the planning of an expanding enterprise. New laboratories are to be built near Maidstone in Kent.

Applications for this post will be treated in strict confidence and should be addressed to :

The
Group Personnel Officer,
Albert E. Reed & Co. Ltd.,
Larkfield,
near Maidstone, Kent

quoting ref. No. SP/GR/58.

RESEARCH PHYSICIST required by Turner Brothers Asbestos Co. Ltd. (Member of the Turner & Newall Organization). The Company manufacture a wide range of asbestos products which are used in all major industries. The present vacancy is in the Asbestos Research Department where the work is concerned with the scientific investigation of existing and new processing methods. The candidate obtaining this appointment is expected to be of degree standard or equivalent academic attainment and have preferably experience of research work, to be unafraid of responsibility, and be able to work on his own or with a team as the situation demands. Experience in textiles will be advantageous. Salary will be commensurate to responsibilities. The Company operate a Pension and Life Assurance Fund and provide the usual welfare amenities. Letters requesting an application form should be addressed to the Personnel Manager, Turner Brothers Asbestos Co. Ltd., P.O. Box 40, Rochdale, and the envelope should be endorsed "Research Physicist."

Hammersmith Hospital and Postgraduate Medical School, Du Cane Road, London, W.12. Applications are invited for the post of PHYSICIST (Basic Grade) in the Physics Department. The work will be initially on problems associated with radium and X-ray therapy and diagnosis and later with radioactive isotopes. Opportunity for original work and some teaching duties. Experience desirable but recent graduates welcomed. Commencing salary within range £645 – £700 (Honours), £570 – £645 (others), rising to £1,035 plus London Weighting. Detailed applications, naming two referees, to Secretary, Board of Governors.

PHYSICIST

Aged 25-35 with good academic qualifications and preferably some industrial experience to take charge of a central laboratory engaged in the testing of rubbers and plastics. The work will include study of the functional performance of materials and their interpretation in terms of measured physical properties, development of test methods; processing data in connection with the drawing up of specifications and standards in co-operation with other organizations; and general supervision of personnel engaged in the physical testing of rubbers and plastics according to standard procedures. The man appointed will be expected to work closely with other technical personnel engaged in technological research and development work with rubbers and plastics. He will have an excellent opportunity of developing a post of responsibility and gaining a wide experience of the properties and use of new materials. This post offers an excellent starting salary and career prospects; non-contributory pension scheme. Please send written applications giving details of age, qualifications and experience to: The Personnel Department, Monsanto Chemicals Ltd., Monsanto House, 10/18 Victoria Street, London, S.W.1.

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DEPARTMENT OF SUPPLY

PHYSICS OF PHOTOCONDUCTION

Applications are invited for the following temporary position at the Defence Standards Laboratories, Finsbury, South Australia :—

Position : SCIENTIFIC OFFICER, Grade 3.

Salary : £A2,005 – £2,265.

Duties : Basic studies relating to the effects of light, X and gamma radiation on photoconductive materials, and the physics of electrophotography.

Qualifications : Honours degree, and research experience.

Conditions : Although the above position is classed as temporary, the successful applicant may choose to enter into an agreement for a three (3) year contract of employment in Australia. In this case, the Commonwealth will bear the cost of removing the successful applicant's furniture and effects up to a maximum of £500 (Aust.), £250 each way.
Under specified conditions, first class air/sea transport for the appointee and dependent's (Wife and dependent children) will be provided by the Commonwealth. Salary payable from date of embarkation.

Applications : Forms obtainable from Senior Representative (AV.49/10), Department of Supply, Australia House, Strand, London, W.C.2, with whom applications should be lodged by March 28, 1960.

UNIVERSITY OF CAPE TOWN

LECTURER IN PHYSICS

Applications are invited for a vacant lectureship in physics. The salary scale is £1,340 × £60 - £1,760 per annum. The duties of the lecturer will include teaching and laboratory supervision of students and some examining and organizing of courses. Applications (with copies of testimonials) should state age, qualifications, experience, and research work completed or in progress, and give the names of two referees whom the University may consult. Two copies of the application must be sent to the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1 (from whom memoranda giving the general conditions of appointment and further information about the work of the department should be obtained) not later than March 22, 1960. A third copy must be sent direct by airmail to the Registrar, University of Cape Town, Private Bag, Rondebosch, C.P., South Africa, by the same date. The University reserves the right to appoint a person other than one of the applicants or to make no appointment.

ESSEX

MID-ESSEX TECHNICAL COLLEGE AND SCHOOL OF ART

MARKET ROAD, CHELMSFORD.

The following new post is available from September, 1960, due to expansion of work:—LECTURER IN PHYSICS to teach at H.N.C., degree and diploma level. Candidates should have a good honours degree, with research or industrial experience, and be able to teach a branch of applied physics, preferably electronics. Salary in accordance with the Burnham Further Education Report, 1959, viz: Lecturer £1,370 × £35 × £40 to £1,550 p.a. Details and forms (stamped, addressed foolscap envelope) from the Clerk to the Governors to whom completed application forms should be returned within 14 days of the publication of this advertisement.

MIDDLESEX HOSPITAL MEDICAL SCHOOL

DEPARTMENT OF PHYSICS APPLIED TO MEDICINE

Applications are invited for an appointment as ASSISTANT PHYSICIST. The duties will be concerned mainly with assisting in teaching of postgraduate courses in radiation physics. Applicants should have an Honours Degree in physics and some postgraduate experience in radiation or nuclear physics. Facilities for research will be available. The appointment will be in the lecturer grade on the salary scale starting at £960 per annum (including London Weighting), and the post will be superannuable under the F.S.S.U. Applications, giving full details of age, qualifications and experience, together with the names of two referees, should be sent as soon as possible to the Secretary, Department of Physics Applied to Medicine, Middlesex Hospital Medical School, London, W.1.

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   Ph.D. or 1st or 2nd Class Hons. Degree in Physics with some research experience and preferably mathematical ability
2. **Two Physicists**
   Hons. Degree in Physics or good General Degree.
3. **Assistant Physicist**
   General Degree or H.N.C. in Applied Physics.

The Department is mainly concerned with Research into the properties of special steels and the manufacture of large forgings. Much of the work is fundamental in character, e.g. heat flow problems, residual stress measurement, hydrogen diffusion in steel, metal deformation, and there is opportunity for original work. The Laboratories are in Sheffield within five miles of the Peak District National Park: Five day week: Sports Club: Pension Fund: Salaries commensurate with qualifications and experience:

Applications to:

The Personnel and Employment Manager
THOS. FIRTH &
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Atlas Works, Sheffield, 4.

THE INSTITUTE OF PHYSICS

Vol. 11 No. 3 **BULLETIN** MARCH, 1960

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A New Realism in Physical Theory

G. WYLLIE
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University of Glasgow

[Based on the Chairman's Address to the Scottish Branch of the Institute, given in St. Andrews on October 16, 1959, and subsequently in Edinburgh and Glasgow]

REALISM is not a new idea even to theoretical physicists, and the development of physical theory involves a continuous approximation to a structure isomorphous with the facts. The aim of this talk is to draw attention to a particular aspect in which recent theories try to improve on their predecessors—by a lessened reliance on the fallacy of the isolated system.

It is widely accepted that the natural world is in some sense real. There are those who regard all natural phenomena as created by their consciousness—a view held almost exclusively by persons ill acquainted with such phenomena: natural philosophers, however, are too well aware of the angular and refractory character of natural facts to fall into any such delusion. Whatever webs of ingenuity we may spin over the tea-table, we are in our working lives "naive materialists" of the crudest sort.

Philosophers of the other sort allege nowadays that the only business of philosophy is to examine, not even the meaning, but the use, of words. If for words were substituted "language" in a broader sense, something might be said for the claim; let us begin in the fashion by examining some uses of "realism." In an age which took coherence of discourse more seriously than is now popular, realism was the name for belief in the reality, not merely of physical entities, but of metaphysical ones, and a fruitful field for folly to reap confusion. More recently, we have tended to use realism for a quality rather than a doctrine—the quality of correspondence or isomorphism between a theoretical model and the facts it is intended to cover.

Unfortunately our judgement of facts, as distinct from our acceptance of individual experience, is based on a socially accepted view of reality. Thus philosophers whether natural or not talk as if the "real" picture of any given situation is that constructed from the out-dated scientific notions current in their circle of communication. The working scientist is simply less out of date in his own special field than his colleagues in other disciplines.

Before the—relatively recent—development of natural philosophy, the diversity of nature was unified only in the fact of human experience, seen teleologically in reference to human or divine purpose. This is a natural and convenient attitude of mind, since it imposes on experience an order conformant to human necessity. A higher development is the Jewish philosophical view, which we inherit, of the unity of nature as a unity imposed in the act of a single creator. From this point of view it is merely perverse to distinguish natural from divine law, and the universe is necessarily *wholly* intelligible—even if not in human terms. The modern trend away from this line of thought derives from the rise of experimental philosophy and the emergence—and recognition—of science as a principal human activity.

A useful metaphor for scientific investigation is that we are engaged in a dialogue with nature—largely indeed conducted at cross-purposes, but with a steadily improving coherence and breadth of discourse. In terms of the metaphor, the notion that the universe is entirely intelligible amounts to saying that nature talks perfect sense in an unknown language whose terms and syntax it is our task to discover: our first key to nature's language is our own animal character, the fact that our needs and satisfactions in the main depend directly on the natural environment. While it is not unreasonable to suppose that nature talks more sense than we do, the stronger hypothesis is hard to define and probably impossible to verify; we are hardly entitled to assume much more than that the natural world is rational enough to have supported the evolution of such partly rational animals as ourselves.

We would hope to be able to say that nature never spoke ambiguously, but the rule that silly questions get silly answers applies to this conversation as to others. What nature gives us is the response to our own exploratory activity, at all levels from simple perception up. The experiments of Professor Ditchburn[1] and his colleagues at Reading on the fading of stabilized visual images illustrate this particularly nicely; and the discomfort of a person listening to stereophonic sound with earphones arises from a similar unnatural stabilization of his aural field. At the conceptual level, experiment plays a double role in that the actual behaviour of the experimental rig lies unambiguously in the natural world, while its structure is arranged to reflect our existing ideas of how that world behaves. An experiment arranged to give a yes-or-no answer to an apparently simple question is thus specially instructive when by answering yes-and-no it reveals an inadequacy in the terms of our question: an unambiguous answer would have added to our information; the ambiguity may be the key to a fresh insight.

At any rate it is an essential part of the program of science to suppose that nature has reasons yet to show us, and that our own criteria of satisfying reasons may need to be adapted towards nature's. One critical point of natural philosophy is Newton's hypothesis of *universal* gravitation. This extends to the whole world a hypothesis found useful within the solar system, and unifies the cosmos under a physical law whose independence of time and non-teleological form give a new type for our image of physical reality. Such notions still dominate our thinking.

To a mind imbued with ideas of universal interaction, reality in the strict sense is a property only of the whole universe. Every conceptual separation of part only of the physical world for consideration constitutes falsification and unreality. In physics, however, the separation can often be made with apparent success, in that the environment of the system in question imposes only such general conditions on the behaviour of the system that no detailed examination of the interaction of system and environment need be made. After all, Newton's development of mechanics was conditioned by the fact that the solar system is so nearly an isolated system, at least in this sense.

In biology, on the other hand, the isolated organism is meaningless if you want information other than anatomical, anything deeper than a count of toes or whiskers. The physiology of the functioning animal involves at least the physical environment, and usually the biological as well. For proper understanding, the biological unit is the ecological system—the whole population of different organisms interacting with each other and their physical surroundings.

For the remainder of this talk, I consider three aspects of the action of the environment in physics. The first is the influence of the very distant environment in determining the dynamics of a system. The second is the profound richness of the physical vacuum as an environment. The third is the damping effect of a thermal environment.

ROTATION IN CLASSICAL MECHANICS

Newton stated his first law of motion in the form—

Corpus omne perseverare in statu suo quiescendi vel movendi uniformiter in directum, nisi quatenus illud a viribus impressis cogitur statum suum mutare.[2]

Evidently the uniformity of a motion will be differently judged according as it is measured with respect to different reference objects, and Newton discusses this perfectly clearly in the preceding scholium to the *Definitiones*, where he postulates an absolute space: uniform translation with respect to this space is not, he says, detected by mechanical experiments whereas rotation with respect to it is for example shown (*ut ipse expertus sum*) by the concavity of a rotating water surface, independent of the relative rotation of its containing vessel. The orientation of Newton's absolute space is more sensitively established by the reference frame in which the motions of the solar system are accounted for by the inverse square gravitational attraction, with no centrifugal or Coriolis effective forces; directions in this are fixed with respect to the mean directions of the fixed stars.

Newton was content, in the *scholium generale* at the end of the third book of the *Principia*, to refer his absolute space to divine presence—

Durat semper, et adest ubique, et existendo semper et ubique durationem et spatium constituit.

Two centuries later, Mach rephrased the question through the following problem. Given an isolated gravitating fluid body with no reference body for the recognition of rotation, will its equilibrium form be spherical or spheroidal? The accent on Newton's answer, "*God* knows!" having slipped, Mach speculated that the local "absolute" frame of reference, rotation with respect to which determines the fluid form, might itself be physically determined by the distribution and motion of distant gravitating matter.

In Einstein's general dynamics the first law of motion is replaced by the statement that a particle subject to no force will travel on a geodesic path, in a space-time whose geometry is no longer that of Euclid. The metric of this Riemannian manifold, which determines the geodesic paths, is itself determined by the distribution of mass. Gravitational force disappears, and the geodesic paths almost coincide with the classical orbits. A peculiar difficulty of the theory is that the principle of superposition is not valid, since the fundamental equations are not linear: thus almost all the problems which have been solved without doubtful mathematical approximations discuss local systems with a Newtonian spacetime (or rather Galilean, in the usual terminology) imposed as a boundary condition.[3] This of course evades the Mach problem, but makes tractable the interesting question whether large rotating masses could be said to drag the local "absolute" reference frame round with them. The two body problem with spin has been treated originally by Lense and Thirring,[4] and recently in more generality by Hönl and Maue[5] and by Riabushko and Fisher,[6] predicting an effect which is unluckily too small to observe in the solar system. It is possible but doubtful that an effect might be found in the rotation of the Galaxy, but the mass distribution in the Galaxy is far too uncertain for any test to be made.

The Mach problem itself belongs rather to cosmology, but the tractable cosmological models bear too little resemblance to our universe for the problem to be considered solved. That the distant environment does determine the Galilean frame which bounds our local system, has however become highly plausible.

PARTICLE AND FIELD[7]

If we now turn our attention, so to speak, from international affairs to the family circle, to the interaction of an "elementary" particle with the field immediately surrounding it, we find matter of much interest. It is well known that the electromagnetic energy to be associated with a point particle is infinite even in classical theory: if a total charge e is distributed with spherical symmetry entirely inside a concentric sphere of radius a, the electrostatic energy associated with the field outside the sphere is proportional to e^2/a; if a total magnetic moment μ is similarly distributed, the corresponding magnetic energy is of order μ^2/a^3, in appropriate units. Evidently if the electron, say, has a sufficiently extended structure it will be possible to ensure that the total electromagnetic energy of the electron at rest is not more than the rest energy mc^2 computed from its mass; but it is not possible to account for the behaviour of fast (relativistic) electrons in terms of this extended structure. The hope that such difficulties will diminish in quantum theory is not immediately justified.

As, in classical mechanics, the normal frequencies of a system are altered by its coupling to an external set of oscillators, so in quantum theory are the energy levels of a system altered: this holds in particular for the coupling of a charged body to the electromagnetic field. By an appropriate Fourier analysis, the field can be represented as a set of non-interacting oscillators, each of which is coupled to the charge. The steady states of motion of the whole system are calculated by the standard device of perturbation theory, in which one envisages the system as moving through the whole series of states which are coupled by the interaction. An important point is that intermediate states with energy different from the energy eigenvalue of the steady state are in fact accessible provided that they are traversed rapidly enough. In terms of the uncertainty principle for energy and time an energy ΔE can be borrowed for not longer than Δt, where $\Delta E \Delta t \sim \hbar$. The effect of this is clearly seen when two electrons interact through the emission and absorption of photons. When the electron separation is r, the time of flight of the photons between them is r/c, so the interaction will be mediated almost entirely by photons of energy up to $\hbar c/r$; it is plausible, and in fact true, that this gives rise to the Coulomb potential.

When one considers the field round a single electron, however, there is no minimum distance set by the conditions of the problem, photons of indefinitely large energy are continually emitted and reabsorbed, and the electron has a corresponding staggering motion of infinite kinetic energy. The infinity arises in the form of a strongly divergent integral over the momenta of the virtual photons. Careful use of the exclusion principle reduces the divergence to logarithmic, and a cut off of all photons of wavelength less than $(\hbar/mc)\exp(-137)$ gives a satisfactorily finite rest-mass. Such a cut-off is analogous to the imposition of a finite radius in the classical case (though this is of course a far smaller distance) and meets the same difficulty, that it is not relativistically invariant.

The resolution of this difficulty was suggested by Kramers and developed by Bethe, and more recently by many others. The philosophy of the matter is fairly simple, though the technique is not. One normally starts the perturbation calculation by assigning a "bare" mass m_o to the electron, and ends with an additional electromagnetic mass δm. Now, neither of these is a physical observable; only $m_o + \delta m$, the total mass, means anything. Let us make $m_o + \delta m$ equal the finite experimental mass, and explore the consequences.

First of all, it is found that this renormalization can be done in a consistent and relativistically invariant way; second, and more important, calculations on the new basis give correct values for two fine-scale phenomena not predicted by the older theory—the difference in energy of the $2s_{\frac{1}{2}}$ and $2p_{\frac{1}{2}}$ states of the hydrogen atom, and the anomalous magnetic moment of the electron.

This degree of success gives confidence in the physical picture employed, but what a picture it now is! In place of the simple elementary particle we have an amoeboid entity surrounded by writhing pseudopodia made from every other sort of particle with which it interacts, the heaviest inside and the lighter ones progressively further out; the vacuum, so far from being empty and at rest, is a boiling hubbub of virtual entities further enriched by every new particle that is discovered; and every such new particle contributes a further layer to the investment of every particle already known. The properties of no single particle are understood without those of every other sort.

In the spirit of the preceding section, one can enquire whether the behaviour of a particle might not be referred to its interactions, not with an immediate host of virtual entities, but with the other real particles, its near or distant neighbours. The notion that two atoms connected by the emission and absorption of a photon are in physical contact, however far apart in space and time, belongs to this order of ideas.[8] The prospect of restoring peace and vacancy to the vacuum is an attractive one, but very little has yet been done on such a program. Whether that ambition is fruitful or not, it has become clear that even such private properties of a particle as its mass can only be understood when the particle is clothed with all of its potential interactions.

THERMAL ENVIRONMENTS

In the last section we considered elementary particles in a vacuum, interacting only with virtual excitations of the various physical fields. In a more general situation, these fields will bear a greater or smaller number of real excitations, so any system we consider must have a material environment of which we cannot expect to have more than statistical information.

Classical thermodynamics at its most general level deals with the steady state of an open system which exchanges energy and material with an environment characterized by the parameters temperature, pressure, and the chemical potentials of its components. Statistical thermodynamics covers the same problem, the thermodynamic parameters now appearing as averages of

microscopic quantities, and in addition determines the probabilities, but not the lifetimes, of fluctuations of energy or concentrations in the system away from their average values. It is interesting that the important fluctuation-dissipation theorems, relating the over-damped response of the system to small driving forces to the probability distribution of the corresponding fluctuations, emerge without further consideration of the environment provided that the driving forces are field forces. The most familiar example of these results is the Nyquist theorem which states that the mean square voltage fluctuation per unit frequency band-width, across a resistance R at temperature T, is $4RkT$ at low enough frequency.

A further development of statistical theory is needed both to derive the response to driving forces large enough to lift the system well away from its original condition, and to discuss the life-times of those fluctuations which can only relax by exchange of energy or material with the surroundings. Interest in such studies has been sharpened in the last decade by the remarkable behaviour of nuclear magnetism. Many nuclei possess a spin moment and an associated magnetic moment, which may be very weakly coupled to the other modes of motion of the atoms or molecules. The nuclear spin system can then be manipulated electro-magnetically and treated as a distinct physical system immersed in a " heat bath " composed of the other degrees of freedom of the sample: its extraordinarily small coupling to the heat bath makes it possible to raise it to indefinitely large temperatures, and indeed the upper bound to the magnetic energy levels makes it possible to reach negative absolute temperatures—with an inverted distribution over the energy states—which are hotter than any positive temperature. The theory of the more complex effects observed is still very incomplete.

From a slightly shifted view-point, we consider a system immersed in an environment of which we have at most statistical knowledge and enquire under what conditions we can give a fairly simple account of the system's behaviour. The type of such a theory is Langevin's description of Brownian motion. Here we have a particle immersed in a fluid which undergoes small random movements. The particle is subject to a fluctuating force which contains a systematic damping of any continued motion, and if we suppose this damping linear the motion is described by the Langevin equation

$$\frac{dv}{dt} + Bv = A(t)$$

where $A(t)$ has now zero average value irrespective of the behaviour of v. The condition that the mean square value of v must correspond to equipartition of energy at the temperature T of the fluid then suffices to determine the spectrum of v in terms of B and T, provided that the correlation time of A is short compared with the correlation time $(1/B)$ of v.

The quantum mechanics of Brownian motion has been developed by Kubo, Bloch and other workers.[9] The essential condition for a simple description is again that the correlation time or relaxation time of the system should be long compared with the correlation time of the fluctuating force acting upon it. It is interesting that correct results can only be obtained by quantum mechanical treatment of the environment as well as the system: a quantum system with a classical environment is a nonsense. The reason is that the system can achieve a thermal equilibrium at finite temperature only through spontaneous transitions, which can only occur when the motions of the environment follow quantum rules. This is well known in the special case that the environment consists of the electromagnetic field, but tends to be forgotten otherwise.*

RECAPITULATION

The conceptual separation of system and environment is not only convenient but necessary for scientific study.

Nevertheless it is an inevitable source of fallacy. Its utility in physics rests on our ability to find interesting situations where the conditions imposed on the system by its environment are simple and general.

We have considered in outline three classes of environmental condition imposed by the far universe, the immediate vacuum, and a generalized heat bath respectively.

* There is a very useful device of physical theory in which a system of many similar subsystems is treated by isolating a subsystem and treating the rest as an environment, then feeding the estimated behaviour of the subsystem into the environment and looking for self-consistent conduct of the whole system within this description. Provided this artifice is clearly understood as a trick of the trade and not a physical law, it need never cause trouble. Unluckily, in the situations where it is most necessary to use it, it is usually impossible to satisfy the conditions of validity for a simple description of the behaviour of each subsystem. I mention the device only to avoid confusion.

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Recent Work in Atomic Spectroscopy

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[Based on a talk given to the Applied Spectroscopy Group at the Institute's House on May 10, 1959]

INTRODUCTION

THE greatest attention to atomic spectroscopy (i.e. the study of light in the form of lines emitted or absorbed when there are transitions between the electron levels of an atom), took place in the years immediately preceding 1939. Verification of various physical theories and interest in assigning spectroscopic lines to electron levels made the subject popular among physicists. Towards the end of the period the attitude of the theoretical physicists is summed up by the quotation in the preface of a book written in 1935, which surveyed the status of the problems of interpreting the line spectra from atoms. The authors maintained that " the interpretation seems to us to be in a fairly closed and highly satisfactory state. All known features of atomic spectra are now at least semi-quantitatively explained in terms of the quantum mechanical treatment of the nuclear atom model." The experimental spectroscopists felt a little more pessimistic as they surveyed the problems that the more complex spectra seemed to pose. Many concentrated on the development of better experimental techniques but before the apparatus could be used extensively emphasis was being placed on other aspects of the atom. Nuclear problems attracted most attention.

The use of spectroscopy has not declined however and in this article examples from spectrochemistry, isotopic analysis and plasma physics are given as well as a brief account of advances in more fundamental studies.

SPECTROCHEMICAL AND ISOTOPIC ANALYSIS

It is true to say that over the last ten or fifteen years the basic techniques to record both the presence of atomic lines and their intensity (which are used as specific indication of elements and their concentration respectively), have remained the same with improvements in sensitivity and in the field of application. Perhaps the greatest emphasis has been on the development of direct recording and grating instruments, the former giving instantaneous readings and avoiding delays or errors inevitable with photographic plates, and the latter giving the higher dispersion which the increasing complexity of the problem is requiring. In the field of nuclear energy there have been big demands for the analysis of impurities in materials containing a large proportion of uranium or plutonium or rare earth metals. The spectra of these are very complex and straightforward spark procedure often does not give a clear cut answer in analysis. Various techniques have been devised for reducing these background effects due to these complex spectra. One known as the carrier distillation method developed by Scribner involved the use of a fairly volatile material such as gallium or silver chloride which increases the evaporation rate of impurities from the sample. This enables the spectra of the impurities to be taken before the spectra of the complex material such as uranium become apparent. Other methods of dealing with this problem have been developed. In another method there is a separation of the impurities from the bulk material before spectral study. The sample is first heated in some type of furnace, and the impurities are driven off ; these are collected on an electrode and it is this electrode itself which is put into the spark or arc chamber. In this way the authors claim that they have been able to use a bigger sample because the spectrum is no longer dominated by the many lines of such material as uranium or plutonium. Ion exchange columns have also been used to separate, say, plutonium from the impurities (with the possibility of effective concentration of the latter). Another example of recent spectrochemical development is that of estimation of gases in metals. This has always been a difficult problem to handle by any means, but Fassel and co-workers in the United States have over the past few years developed techniques whereby certain gases in metals can be estimated by spectrochemical means. By use of a high current d.c. arc in an argon atmosphere the estimation can be made.

Isotopic abundance analysis is a subject which has become much more important with the arrival of the nuclear energy program. The slight difference of wavelength in lines from isotopic elements has been used for this purpose. Two elements with isotopes that have great importance occur at either end of the periodic table, hydrogen at one end and uranium at the other. The estimation of the hydrogen : deuterium ratios has been carried out largely by molecular spectroscopy but use has also been made of the emission lines of hydrogen and deuterium to determine their relative proportions. The fact that natural uranium contains a mixture of ^{235}U and ^{238}U and this ratio is changed as the uranium undergoes fission is extremely important and the ratio of these two isotopes as well as those of less abundant species such as ^{234}U and ^{236}U are quantities that need determination. Much of the work has been done by mass spectrometry, but in recent years it has been found possible to determine the ratio using certain lines of the atomic spectrum. In general high resolution is required and considerable help may be forthcoming for isotopic analysis by the development of interference filters and associated techniques.

It has always been the case that for high resolution interferometers of the Fabry Perot type are required,

and these have been much used for academic research. For industrial use, however, they suffer from various defects but in the last few years the use of dielectric coatings has meant that the intensity of light transmitted by these is much greater. In addition the filters for cutting out unwanted light have also been made much more satisfactorily.

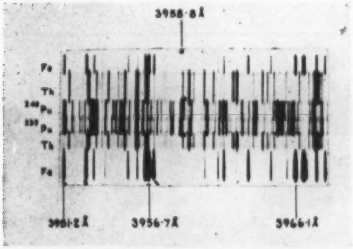

FIG. 1. A section of a photographic plate of plutonium taken at a dispersion of 0·5Å/mm showing the spectra of Fe, Th, ^{239}Pu, and ^{240}Pu. The isotope shift in the line 3958·8 is seen in the complex Pu spectra. The relative scarcity of iron standards is noted in contrast with the more evenly distributed Th lines—(*taken from L. Bovey and H. Wise, A.E.R.E. Report C/R 2976, 1959*).

PLASMA PHYSICS AND ASTRONOMY

The great problem in connection with the work going on in the field of controlled thermonuclear reactions is to examine discharges without disturbing them. There are various methods available but as astronomers have already developed spectroscopic means of determining conditions in inaccessible objects such as stars these astrophysical techniques have been used for much of the work on such devices as "Zeta" and "Sceptre." As is known, these experiments are concerned with the passage of a high energy discharge through deuterium gas at low pressure and the examination of the results to see if thermonuclear reactions occur. One important measurement required is that of temperature. That of the ions can be determined by spectroscopic means using the Doppler effect. In principle the width of a line if only Doppler broadening is involved can be calculated very simply from the following formula :

$$T = 1{\cdot}95 \times 10^{12}\ M \frac{(\Delta\lambda)^2}{(\lambda)^2}\ \ ^\circ\mathrm{K}$$

where $\Delta\lambda$ is the wavelength shift at a wavelength λ and M is the particle mass in units of the proton mass. Since the discharges are at a temperature of about 1,000,000° (90 electron volts) neutral atoms are not present but highly ionized atoms, from impurities in these discharges such as the 2718Å lines of oxygen *V*, could be used for width measurement.

With experiments in "Zeta" and "Sceptre," the width of a line came out to be 1Å and this can be easily measured on an instrument of comparatively low resolving power such as the Hilger medium quartz spectrograph. The difficulty, which is still the subject of

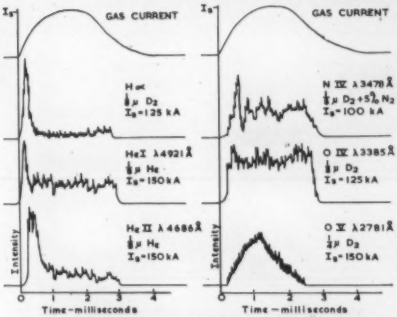

FIG. 2. Variation of spectral line intensities with the current pulse passing through "Zeta." The atomic line studied, the pressure (in microns) of the gas through which the discharge took place and the maximum discharge current are given on the graphs—(*taken from G. N. Harding, S. A. Ramsden et alia, Paper P/1520, Proceedings of Peaceful Uses of Atomic Energy Conference*, **32**, 365, 1958).

controversy is whether the width of these lines is entirely due to Doppler broadening ; the widths could, for example, be caused by a statistical distribution of the Doppler shifts due to movements of the whole mass of the emitting gas. Another application based on the emission of these lines is the determination of how these highly ionized lines are distributed in time and in space.

In addition to the diagnostic application, the interest created by problems of plasma physics, means that high temperature sources have been much more intensively studied. One interesting application emerging from Germany in the last few years has been the high temperature arc. In these a high powered arc with

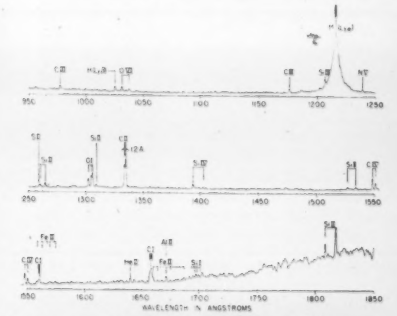

FIG. 3. Atomic spectra recorded in a rocket spectrograph—(*taken from F. S. Johnson, H. H. Malitson, J. D. Purcell and R. Tousey, Astrophysical Journal*, **127**, 80, 1958).

some 140 kW of power passes through a hollow tube of water which gives the possibility of obtaining temperatures up to about 50,000°K. Most of the work has been done with water as the cooling material and the spectra are dominated by lines of hydrogen and oxygen.

The advances in plasma physics partially developed in the search for controlled thermonuclear reactions may lead to advances in spectroscopic knowledge in contrast with the use of spectroscopy as a probe and a tool.

In astronomy there have been several instrumental advances connected with trying to record spectra. One of the more technically significant advances has been the use of rockets to avoid absorption effects by the atmosphere surrounding the earth. Several well developed and reasonably high resolution spectra of the sun have been taken by rockets sent up to about one hundred kilometres. Most of the ultra violet spectra obtained are known in the laboratory. At the other end of the spectrum, in the infra red, spectra have been taken which have not been correspondingly measured in any laboratory source.

"ACADEMIC" SPECTROSCOPY

In the last 15 years there have been great improvements in technique both at the ultra violet and the infra red end of the spectrum. A certain amount of what may be called classical spectroscopy is still being carried on and has been improved by these experimental advancements. One such academic study has been made by Herzberg in Canada on the Lamb shift. In this the Dirac theory of the levels of the hydrogen atom has been shown to be inadequate and by very painstaking and

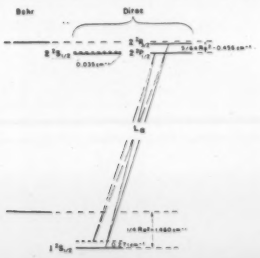

FIG. 4. Energy level diagram for Lamb-Retherford shift in hydrogen. Energy levels $n = 1$ and $n = 2$ of hydrogen according to the Bohr theory at the left, according to the Dirac theory at the right. The quantum-electrodynamic levels, where different, are indicated by heavy broken lines—(*taken from G. Herzberg, Physics in Canada*, **13**, 8, 1957).

extremely accurate ultra violet spectroscopy, Herzberg has confirmed by direct spectroscopic means both the theoretical deductions and the results of microwave experiments. The basis of the method was to measure the absolute wavelength of the Lyman-alpha line of deuterium at 1215Å to an accuracy of 1 part in 10^6; development of wavelength standards was an essential part of the work.

There is still considerable interest in the field of isotope shifts and hyperfine structure determinations. This is partly influenced by information they can give about nuclear structure.

One main item of progress in atomic spectra has been the issue of energy levels collected in a series of books. Volume 1 contains 23 elements from hydrogen to vanadium with 205 spectra. Volume 2 issued in 1952 contained 18 elements (152 spectra) while volume 3 coming out in 1958 had 34 elements, from molybdenum to lanthanum and hafnium to protactinium. Volume 4 will probably be delayed because it will contain information on the rare earths and the heavy elements (beginning with thorium) and very few of these have been analysed. One difficulty in the analysis of the rare earth spectra lines is the lack of people still interested in the problem. In 1933 the volume of *Physical Review* contained over one hundred papers on the subject but the 1956 volume had only two papers.

An experimental difficulty from a practical viewpoint is the large number of lines produced which arise from the very complex electron configuration of these elements. One therefore needs high dispersion instruments and although interferometers can be used, wavelength measurement with these is a very slow process. In the United States, several high dispersion gratings have been built. One of the most notable is that of the Argonne where a 30′ Paschen Runge mounting has been built giving a potential wavelength determination accuracy of 1 in 10^7. In addition to the experimental problems of obtaining this high accuracy are the auxiliary requirements in wavelength standards. Wavelengths of unknown spectra are determined by comparison with others and therefore these standard spectra are very important. In recent years developments have occurred which show that the iron arc, which has been the normal laboratory standard, is unsatisfactory in many

FIG. 5. View of measurement section of modern spectroscopy laboratory; the plates are measured on the travelling microscope by use of a photo electric technique of comparison which avoids eye strain. The readings on the screw are automatically punched onto cards from which the wavelength data can be derived on a computer—(*photograph of Argonne National Laboratory, Lemont, Illinois, courtesy of Dr. F. Tomkins*).

respects, such as scarcity of lines in some regions and lack of reproducibility of the line wavelengths. These are two of the reasons for changing to elements such as thorium which has many more lines uniformly spaced and therefore gives the possibility of a more uniform standard system. (It may be said in passing that both the atomic clock at the National Physical Laboratory and the standard of length rely fundamentally on atomic spectra since in the former the hyperfine structure of the caesium atom is used for controlling the frequency and the latter involves an atomic line.)

In addition to high accuracy of measurement and good standards one wants some means of rapidly measuring these tens of thousands of lines without too much fatigue in the scientist and too much risk of errors in copying the data down. Several automatic measuring methods have been developed. In one the position of the screw used in measurement is recorded automatically by a device known as a digitiser and the data printed out. Another developed in this country, involves the use of two gratings which when moved relative to one another produce a series of moire fringes which can be counted. Photo-electric devices have also been used to replace the measurement microscope to reduce strain in the visual examination of photographic plates.

It is also important to produce high intensity sources of light which give fine lines and in which very small quantities of metals can be particularly used. One such satisfactory source is that involving an electrodeless discharge. In this the halide of the material is sealed off with a rare gas at 2-3 millimetres pressure in a quartz tube and the spectrum excited by microwave radiation at 2,425 mega cycles per second. Another development has been the use of spectra in the 1-3 micron region in addition to that in the visible photographic region from say 0·3 to 0·7 micron. There are several reasons for doing this ; one is the fact that the wave number decreases and therefore the potential accuracy may be made higher with longer wavelengths ; another is the practical point that very sensitive detectors, e.g. lead sulphide photo conductive cells are now available as well as gratings suitable for the infra red, e.g. manufactured by the Merton process developed by the National Physical Laboratory. Spectra in the 1-3 micron region from microwave sources have been taken and it is expected that these will be of use in elucidating the electronic levels giving rise to transuranic spectra.

Modern computing facilities can be of great help and importance in dealing with the large numbers of lines either in various stages of the experiment or in sorting out the final wavelength data. Since the number of lines is of the order of thousands, fast machines are useful. One essential step in the elucidation of the electron levels is the inspection of the frequencies of lines to find sets of equal differences between pairs. This can be carried out by mechanical means and save a considerable amount of the spectroscopists' time. The main difficulty,

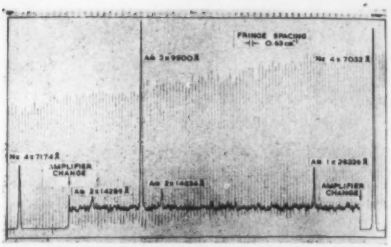

FIG. 6. Spectra of americium in the 1-3 micron region; the fringes are used for wavelength measurements—(*taken from L. Bovey and E. B. Steers, A.E.R.E. Report C/R 2827, 1959*).

however, which cannot be overcome by machines is the confusion introduced by low accuracy in the wavelengths. If the lines can be measured consistently to about one part in ten million, the modern computer would be an even more powerful aid in the determination of the electronic structure of the rare earth and transuranic elements.

CONCLUSION

The post war trend to spectroscopic methods involving radio frequency techniques (e.g. nuclear magnetic resonance) which have many applications to molecular structure problems has considerably decreased interest in the development of atomic spectroscopy. Nevertheless, there has been increased utilization of the results from work already carried out in this field. One hopes that more effort can be put onto general atomic problems. Modern techniques can help progress considerably but a higher number of workers is also required.

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In order to avoid a long list, a few are given which contain detailed references to much of the work discussed in the article. Preference has been given to the most recent literature.

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Notes on Final Year Project Work in the Applied Physics Diploma in Technology Course at Brunel College

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In the sandwich course for the Diploma in Technology in Applied Physics as conducted at Brunel College there is extensive practical work in physics and applied physics in the first three college periods of the course. Practical examinations of a traditional kind are not held, although laboratory notebooks are examined and assessed. In the fourth year of the course instead of formal practical work, students are given a project to work on. The project is a recognized feature of the Dip. Tech. sandwich course, but in view of the fact that only relatively few courses have reached the fourth year there is little actual information available as to what can in practice be achieved in project work and at what sort of standard the work should aim.

At this college the academic period runs from early January to early July, the students complete their final examinations in June, and the course ends in December after a further six months' industrial training. We therefore take the view that the report on the fourth year project, whose preparation is an important part of their training, need not be presented to the college until October. This procedure ensures that the students are not having to work hard for a final examination and also at writing a research report at the same time. It allows time for the project reports to be marked and the final assessments of the students to be made before the end of December.

In the Physics Department at the college nine hours a week are timetabled for work on the project. This means in effect that the student can work in the laboratory for one whole day and one afternoon. Some students have, in fact, taken a little more time than this, others inevitably less, but we adopt the view that students at this level should be regarded as responsible and given an appropriate measure of freedom.

The first Dip. Tech. course in Applied Physics started with nine students in January, 1956, but only six of them reached the third year. Four of these passed the Part I examination in June, 1958. Thus our first group of students (only four in number) took their final examinations in June, 1959. They had been working on their projects for the previous five months and had thus had about 180 hours of experimental work. Their project instructions or terms of reference had been given to them in the previous November so that they had had time to think about their mode of attack before returning for their final college period in January. The subjects chosen were in general of industrial interest ; in two cases they were arranged in connection with industrial or government establishments and in the other two the projects were suggested by the college staff.

It may be of interest to set down in some detail work which was undertaken by the students :

MR. W. T. CLARK (College-based)

Mr. Clark had spent the third industrial period in the Basic Physics Division of the National Physical Laboratory where he was introduced, by Dr. R. W. Powell, to a novel thermal conductivity comparator which he had invented some two or three years previously. It had been developed to the stage of being a useful instrument for non-destructive testing and certain other purposes, but for which no adequate design theory existed in spite of various attempts. Mr. Clark worked on the fundamentals of a design theory for this device, involving fairly complicated heat flow paths between a sphere and an indented plane and had made various new measurements and observations. It was decided that a continuation of this study should form the work for his project. Starting from January, Mr. Clark achieved the following:

(*a*) A satisfactory working design theory for the device. This theory involved some fairly sophisticated mathematical analysis.

(*b*) He also showed how his analysis could be used in conjunction with experimental measurements to determine the actual areas of contact between different planes and spheres.

(*c*) He investigated theoretically and experimentally the variation of contact areas with load.

(*d*) He showed both theoretically and practically how the thermal comparator could be used to determine the thermal conductivities of powders and obtained experimental results for several technical materials.

(*e*) He extended his analysis to the differential flow across a thin film on a solid plane body and showed again theoretically and experimentally how the thickness of thin films on solids could be measured.

Mr. Clark's work was in fact of postgraduate standard in its scope and its success ; the findings and results have been prepared for publication in collaboration with Dr. R. W. Powell.

MR. F. W. WILLETS (Works-based)

Mr. Willets had for several years been employed in the Research Laboratory of Kodak Limited and had worked in his previous three industrial periods on photographic emulsions. His project was arranged in

consultation with Dr. Stevens and Dr. Herz of Kodak and Mr. J. I. Mitchell, Senior Lecturer in Physics, and was concerned with the numbers of sub-structures in the grains of particular X-ray sensitive silver bromide photographic emulsions. It is found that when Laue photographs and photographic emulsions are taken the rings are normally " spotty " in character and the number of spots in a given ring can be related theoretically to the size of the grains of the emulsion. It had previously been found by Dr. Herz that in certain of the rings (notably from the 220 and 200 reflections) the number of spots was not in agreement with the theory and the difference was attributed to some form of sub-structure in the grains.

Mr. Willets was asked initially to modify one of the college X-ray diffraction sets to provide a micro-beam. This he arranged by means of lead glass capillaries. He also made a special camera for use in conjunction with the modified equipment. He was then asked to repeat the results of Dr. Herz and his colleagues using silver bromide emulsions and this he did very quickly and successfully. He tried to investigate the effect on emulsions made of other materials having a similar crystal structure and initially he had some success with emulsions made of silver chloride. He then prepared similar types of emulsions based on sodium chloride. There was no guidance in the literature as to whether an emulstion with grains of appropriate size could be in fact prepared from sodium chloride and Willet's previous experience with emulsions came in useful here. After various attempts he managed to prepare suitable samples for X-ray work from saturated solutions using ethyl alcohol. He was able to obtain a crystal size of roughly 1 micron and to prepare sufficiently large areas of uniform density when dried down on to photographic film base. No supporting medium was used. These coatings were unchanged after three months' keeping. The effects previously found in silver bromide were also found in silver chloride and sodium chloride. Willets followed this work with a fairly careful analysis of the probable errors and reasons for the discrepancies between theory and experiment and in general he performed a very satisfactory and rounded-off piece of work.

D. E. White (Works-based)

The college was unable to arrange a suitable project in conjunction with Mr. White's firm and a problem suggested by Mr. R. V. Sharman, Lecturer in Physics, was offered to him. He was asked to investigate by electro-mechanical methods the modes of vibration of a metal beam excited into oscillation by means of a hammer. He was asked to study particularly the initial transverse vibrations, i.e. the first few cycles, to look at beams of various shape, size and material, and to use hammers of varying degrees of hardness. He arranged a neat system of a pendulum-supported hammer which could be arranged to swing through 180°, to break various micro-switches en route and to hit the beam (supported on knife edges) at some pre-determined position.

A telephone earpiece was used as a transducer and was held near the beam on the side opposite to that at which the hammer fell. The various items of electronic amplifying and triggering equipment were designed and made by Mr. White for use in this experiment. The oscillations of the beam were displayed ultimately on a Cossor oscilloscope and arrangements for fairly fast photography were made by Mr. White. He found that in addition to the expected damped sinusoidal oscillations there was evidence of a fairly large proportion of high harmonics in the first few cycles of the beam. He made various attempted syntheses of these wave forms which were moderately successful. More importantly he noticed that the first cycle of vibration was always shorter in duration than the subsequent regular oscillations. This was found not to be instrumental in origin, but fundamental to the initiation of vibrations in a beam supported in this manner. The behaviour was independent of the nature of the metal beam and of the type of hammer used. The phenomenon of acoustic dispersion which he found in this sort of structure can be explained if the form of the impulse function of the hammer is known. In Mr. White's experiment this function was not known but he made the intelligent approach of guessing at a function consisting of positive and negative exponential terms and then by means of a Laplace transform method of analysis was able to show how this acoustic dispersion could in fact arise. It is hoped in subsequent years by use of a transducer actually attached to the hammer to find the precise form of this impulse function and to take the work one or more stages further.

The fourth-year students had attended as part of their final year mathematics course a series of lectures on integral transforms in mathematical physics and both Mr. White and Mr. Clark were able to use these mathematical methods in the analysis of their project work.

R. Selkovitch (College-based)

Mr. Selkovitch worked on a problem of high vacuum physics suggested by Mr. D. J. Pacey, Senior Lecturer, and he was asked to construct an ion gauge used as a vacuum pump, to operate it not at the highest vacuum range but in the region around 10^{-6} mm Hg, to calibrate it in various gases, and then to determine its pumping action in these gases. Mr. Selkovitch made a good job of the construction of the gauge used as a pump and produced his own amplifier to drive the pen recorder for his recording of results. He calibrated the pump in several gases but was only able to measure its pumping speed in air. This was partly on account of lack of time and partly because one problem with experiments on high vacuum systems, particularly when they can be carried out on only a day or so a week, is that considerable time may be needed to allow the system to pump down to the level of pressure at which measurements of value may be made. To some extent this may make it difficult to complete a worthwhile piece of work. Nevertheless this experiment will be continued by another student in 1960 who will take over Mr. Selkovitch's equipment and, we hope, measure the pumping speed and the general behaviour of the ion gauge in several different gases.

All the students produced tidy and well-written reports on their projects and some of them are already being prepared for publication in the journals. From

the point of view of the college staff and the Dip. Tech. external examiners there are certain very real problems in assessing the value of a student's project report. If one is examining students for M.Sc. or Ph.D. degree the problem is perhaps relatively straightforward because the student either passes or fails. In the Dip. Tech. however the assessment of the project counts towards the students' final classification. We had decided to allocate a maximum of 200 marks for the project which together with 600 marks for a student's final examination made up 800 marks. As a guide we attempted the following rough breakdown of the 200 marks ; we awarded 100 for the work as such, 50 for the initiative and intelligence with which the problem was tackled and 50 for the presentation of the final results. Each supervisor marked the project reports in accordance with this breakdown and the Head of Department then marked them independently. The agreement between the two marks was remarkably close in all cases, and although our experience is limited, we believe this approach to be a fair and reasonable one. It is interesting that in no case did the assessment of the project differ by more than a few per cent from the student's theoretical examination results.

Some of the problems have opened up further fields for exploration and in January, 1960, when we shall have 12 students undertaking fourth year projects on a greater range of topics two or three of the previous topics will be taken further. We are finding that about half of the students can be provided with projects arranged in co-operation with their firms, but that the college needs a pool of ideas to deal with the other students. Fortunately at present there is no shortage of ideas for suitable work and we can only hope that this will continue. So far only a few of the students have suggested their own projects.

There is no question in my mind that the previous industrial experience of these Dip. Tech. students, frequently in laboratories of the best possible type, has contributed very markedly to the maturity and intelligence which the students display when tackling these problems in college and away from their firms. I believe that this mode of approach to practical work and examination in the fourth year of a Dip. Tech. course is vastly more satisfying for the students and also for the examiners, than the traditional practical work and practical examinations which has characterized so many degree examinations. Both external examiners (one a university professor and the other a leading industrial applied physicist) studied the project reports and visited the students during the academic period to see them in the laboratory. They commended the projects highly.

THE ANNUAL DINNER

Park Lane Hotel, Piccadilly, London,

May 3, 1960

The principal guest is Sir Roger Makins, Chairman of the United Kingdom Atomic Energy Authority, until recently Joint Permanent Secretary of H.M. Treasury and formerly British Ambassador to the United States of America.

Tickets (exclusive of wines) are two guineas each. Graduates under the age of 25 years, and Students of the Institute may have either one or two tickets at 30s. each.

Forms of application for tickets were circulated with the February *Bulletin*. Additional copies are available from the Secretary. Applications should be submitted as soon as possible and not later than April 15.

Notes and News

Amalgamation of The Institute of Physics and The Physical Society

We are glad to report that good progress is being made towards the implementing of the proposals adopted by the General Meetings of the Institute and The Physical Society to amalgamate these two bodies in accordance with the Scheme which was approved by those meetings. All those invited to fill the various honorary offices and to serve as members of the first Council accepted, and met as the Council-elect on January 26 last under the Chairmanship of Sir John Cockcroft. Those serving are :

President : Sir John Cockcroft ; *Presidents of the Institute and Society :* Sir George Thomson, Mr. J. A. Ratcliffe ; *Vice-Presidents :* Professor R. W. Ditchburn, Mr. A. J. Philpot, Dr. W. H. Taylor, Dr. J. Topping ; *Honorary Treasurer :* Dr. J. Taylor ; *Honorary Secretary :* Dr. C. G. Wynne ; *Ordinary Members of Council :* Professor B. Bleaney, Mr. E. R. Davies, Professor B. H. Flowers, Dr. J. M. A. Lenihan, Mr. G. R. Noakes, Professor C. F. Powell, Dr. F. A. Vick, Professor D. A. Wright; *Chairmen of Branches:* Dr. M. R. Hopkins, Professor H. Lipson.

The meeting was opened by Sir George Thomson, the Chairman of the Joint Amalgamation Committee and President of the Institute, who invited Sir John Cockcroft to take the Chair. The draft of the Memorandum, Articles of Association and By-laws which had been prepared by the Joint Committee were laid on the table and the procedure agreed for their examination by members of Council and for their submission to the Board of Trade.

The recommendations of the Joint Committee for the appointment of the executive officers were unanimously adopted. This was to invite Dr. H. R. Lang to be the Secretary of the amalgamated body with Dr. A. C. Stickland as Editor and Deputy Secretary and Mr. N. Clarke as Deputy Secretary.

The Council-elect considered drafts of the constitution and terms of reference of its standing committees and appointed them.

Preliminary consideration was given to a number of other matters and the Council is meeting again on March 9.

Payment of subscriptions

Members are reminded that annual subscriptions became due on January 1. The form that should accompany remittances was included in the January *Bulletin* ; extra copies may be obtained from the Institute if required.

Honours for the President and Honorary Treasurer

The Institution of Electrical Engineers announce the award of the Faraday Medal to Sir George Thomson " in recognition of his outstanding contribution to the advancement of electrical science, of the leadership in research which he has given to others in this field, and of his inspiring services to education in science and technology."

Dr. James Taylor has been elected to Honorary Membership of the Institution of Mining Engineers for his outstanding work on explosives ; the list of honorary members contains only nine names.

Education Group Conference

The Annual Conference of the Education Group, of which details have already been announced, is being held this year jointly with the Midland Branch in Birmingham on April 21 and 22. There will be four main sessions devoted to problems of selection for degree and Dip. Tech. courses ; a comparison of the university degree and the Dip. Tech. as a training for industrial physicists ; postgraduate training in physics ; the requirements of industry. Full details and forms of application may be obtained from the Institute.

International Conference on Medical Electronics

The Third International Conference on Medical Electronics will be held in London on July 21-27, 1960. Further details may be obtained from The Institution of Electrical Engineers, Savoy Place, London, W.C.2.

North Atlantic Treaty Organization : science research grants

The North Atlantic Council has established a fund to give grants for research projects in the field of natural sciences and technology. The grants are primarily for promoting increased co-operation in research among the member nations and to a lesser extent for other scientific projects where international aid is particularly desirable.

Grants will be made for preparatory work which might lead to large co-operative projects and for smaller co-operative projects. To a lesser extent, grants will be made to stimulate increased research in the less developed member countries.

The selection of the recipients of the research grants will be made by a Scientific Research Grants Panel consisting of five distinguished scientists.

The results of research encouraged under this programme will be made available for the benefit of all member countries.

Applications should be made to the Office of the Science Adviser, North Atlantic Treaty Organization, Palais de Chaillot, Paris XVI^{e}, France.

Current Problems in Space Research and Technology

A short vacation course on Current Problems in Space Research and Technology will be held at the Manchester College of Science and Technology from March 28 to April 1, 1960, inclusive. The Organizing Lecturer is Professor Z. Kopal. The course fee is ten guineas. Full details may be obtained from the Registrar, The Manchester College of Science and Technology, Manchester 1.

Reviews of Books

THE TAYLOR MANUAL—ADVANCED UNDERGRADUATE LABORATORY EXPERIMENTS IN PHYSICS

American Association of Physics Teachers

London : Pergamon Press Ltd. Pp. xxv + 550. Price 72s.

Lloyd William Taylor was an American professor who, to judge from the preface to this book, was a well-loved and stimulating teacher of physics. He died in 1948 and left behind him a reputation as a stalwart advocate of the importance of physics in general education, and of the close co-ordination of theoretical and practical physics. This book was commissioned by the American Association of Physics Teachers to act as a memorial to him and to give the kind of guidance that they thought he would have liked to those whose task it is to devise experiments for undergraduate courses.

The book is a magnificent success. The standards are somewhat variable, since 191 people have contributed to it, but it is none the worse for that. Some of the descriptions are long and detailed ; others consist of a few lines followed by references. There are some experiments more suitable as lecture demonstrations. But, by and large, the whole of physics is extremely well covered with a proper balance between the different branches. The committee that produced the book is to be congratulated on its efforts. No one in charge of third-year undergraduate laboratories can now claim to be short of ideas for new experiments or new variations of old experiments.

The chief criticism that may be made is that many of the experiments use too much standard equipment and leave too little to the student's own initiative. Who in this country, for example, would consider giving the student *two* tape recorders to measure multiple time intervals ? Experiments of this type may well induce in students a belief that practical physics cannot be carried out without such expensive aids. But if we restrict ourselves only to the " string and sealing-wax " type of experiment, we may be turning out students who have no idea how to make use of modern equipment.

The book provides material for both schools of thought, and it may well stimulate a complete re-thinking of the place of practical work in the teaching of physics. It can be strongly recommended to university staffs and, moreover, to industrial physicists who may have occasion to carry out an unusual measurement in the course of their work.

H. Lipson.

ADVANCES IN SPECTROSCOPY

Edited by H. W. Thompson

London : Interscience Publishers Ltd. Pp. ix + 363. Price 85s.

This is the first volume of a new series of progress reports, compiled for physicists and chemists who wish to remain up-to-date in all branches of their subject. The subjects selected for review in this volume are the spectra of polyatomic free radicals, spectroscopy in the vacuum ultra-violet, the determination of the velocity of light, high resolution Raman spectroscopy, modern infra-red detectors, the infra-red spectra of polymers ; and the rotational isomerism of certain saturated molecules. These titles show that the book is intended for organic and physical chemists, and pure spectroscopists; analytical emission spectroscopy is mentioned in one paragraph.

The matter is thoroughly up-to-date; since the articles were written by seven different authors in different countries at different dates this is hard to achieve, and two authors have added further references or information at the proof stage. Physicists in several techniques may find the chapter on modern infra-red detectors most instructive ; and they will also be interested by the review of various methods of determining the velocity of light, and of the associated problem of the index of refraction of air. The chapters are entirely independent, and are not numbered, but there has been some attempt to number the equations with reference to the chapters. The illustrations are well reproduced, and the diagrams with one exception are all clear. The book is so much one for the specialist that some abbreviations are left unexplained ; this would make it difficult reading for the average undergraduate ; but for a Ph.D. student concerned in any kind of pure spectroscopy it would be most valuable.

Ernest van Someren.

ANALOG METHODS, COMPUTATION AND SIMULATION

By Walter J. Karplus and Walter W. Soroka

London: McGraw-Hill Publishing Co. Ltd. Pp. xiii + 483. Price 97s.

This is the second edition of a previous book with the same title by Soroka alone. Like its predecessor, it offers a comprehensive treatment of analogue methods and techniques, the main difference being that the emphasis has been shifted from mechanical to electrical and electronic equipment in keeping with the times.

A description of basic linear and non-linear computing elements precedes a discussion of how they may be inter-connected in order to solve mathematical equations including algebraic equations and ordinary and partial differential equations. The sections on mechanical differential analysers have been considerably shortened in order to make more room for electronic analogue computers and simulators, though the chapter dealing with mechanical computing elements has been retained because of the importance of these devices in special purpose computers. There is a passing mention of digital differential analysers. There are chapters on finite difference networks and continuous field analogues such as the electrically conducting sheet.

Attractive features are three appendices. The first contains a table of transfer impedances; in the second

are seventy-nine problems and in the third, ten laboratory experiments. These are suitable for students to attempt. The book is well illustrated by very good diagrams and a few photographs. Perhaps the reviewer may be permitted a personal regret that the only book with the title *Differential Analyser* published in Great Britain is not mentioned, but this is a small omission in a book containing so much valuable information.

J. CRANK.

EYE, FILM AND CAMERA IN COLOUR PHOTOGRAPHY

By Ralph M. Evans

London : Chapman & Hall Ltd. New York : John Wiley & Sons, Inc. Pp. xii + 410. Price 72s.

The author has spent some thirty years in the field of colour photography, much of this time as Director of the Colour Technology Division of the Eastman Kodak Company. He has made an extensive study of the subjective aspects of colour photography and has lectured widely in America and elsewhere on this complex subject.

The basic theme of the book is the fact that what an observer sees when he looks at a scene is usually very different from what he sees when he looks at an "accurate" colour photograph of that scene. The author deals in considerable detail with all the factors that contribute to this general principal and discusses the ways in which the photographer may make use of characteristics of the eye, the film and the camera to attain his own ends.

From one who has paid a great deal of attention to the technique of the demonstration-lecture, the reader might expect a high standard of clarity of presentation and this is one of the outstanding features of this book. Unfortunately, a book does not lend itself as well as does a darkened lecture theatre to the demonstration of many of the effects described and discussed. A considerable number of photographs in black and white and colour are, however, included and do contribute to the appreciation of the text.

This is not an inexpensive book but it can be recommended to those physicists interested in the subjective aspects of vision and to those photographers anxious to acquire more detailed knowledge of the inter-relation of the characteristics of the eye, the film and the camera.

D. T. R. DIGHTON.

OPERATION CALCULUS

By Jan Mikusinski

London : Pergamon Press Ltd. Pp. 495. Price 100s.

Perhaps all books should be written twice in Polish, once in Russian and once in German as this one was before being produced in English. Certainly, the result is a book of remarkable scope and clarity. The author presents his own approach to operational calculus together with its applications. The book is intended to be of use to both the engineer, who regards the operational calculus merely as a tool, and to the reader who is interested in proofs of theorems and mathematical problems for their own sake. Inevitably, this dual aim has resulted in an expensive book which one fears may defeat its own purpose. This would be a pity because there certainly is a good deal here for both engineers and mathematicians.

The starting point of the theory presented is the concept of convolution. From this follow integral and differential operators and then we are back in nomenclature which resembles that of the Laplace transform. Separate chapters deal with applications to electric circuit theory, vibrations of a string and heat conduction. There are outlines of more general theories of linear differential equations with constant coefficients and of partial differential equations. The present edition has been enlarged by the addition of an appendix containing proofs of theorems, new results obtained since the first edition appeared, and a discussion of the relations between the operational calculus and other branches of mathematics. There are numerous examples to which answers are supplied. An extensive bibliography and lists of formulae and tables of functions complete the book. One task of a reviewer is often to point out printing errors but this has been done by the author himself who obligingly lists forty eight misleading errors. This apart, the book is well produced and clearly written and would doubtless have a wide appeal at a lower price.

J. CRANK.

LEHRBUCH DER THEORETISCHEN PHYSIK

By G. Joos

Frankfurt: Akademische Verlagsgesellschaft MBH. Pp. xxiii + 842. Price DM38.

The English third edition of this book is a translation of the German ninth, and the present tenth German edition differs from the previous one only in minor detail, affecting no more than a dozen pages. The book thus remains essentially as we have known it since the English third edition appeared last year and there is no need to praise it again. It is a classic and countless theoretical physicists must have had their first introduction to the subject through Joos. Long may this continue, even though most sadly there will be no further editions. For while the book was going through the press, Georg Joos died. This is no place for an obituary, but ever since I first owned my now much battered first English edition I have felt that I have known him and, though I never met him, I now feel that I have lost one of my teachers. A great teacher.

I had not previously had the opportunity to compare the German and English versions from the point of view of the translator. The translation is good, even excellent, but yet it fails to give the full meaning of the original. We need look no further than the first line. "Eine rein experimentell arbeitende Physik würde . . ." becomes "Purely experimental physics confines . . ." Where is the subtle meaning of the indefinite article, where the oh so essential subjunctive ?

L. R. B. ELTON.

ELECTRON PHYSICS

By O. Klemperer

London: Butterworths Scientific Publications. Pp. xi+248, Price 32s. 6d.

The sub-title of this book is *The Physics of the Free Electron* and this adequately describes the scope. The behaviour and properties of electrons free from other forms of matter are fully discussed. The first half is concerned with the movement of electrons in electric and magnetic fields, electron optics, space charge flow and detection of cathode rays. These are the aspects of electrons which are of importance in valves, cathode-ray tubes, electron microscopes, etc. The second half of the book deals with the nature and precise measurement of the fundamental properties attributed to electrons – mass, charge, wavelength, spin, etc.

The book is based on an undergraduate course at Imperial College, but additional material has been included for completeness. There are provided at the end of each chapter references and some problems (without answers). This text can be recommended for the later stages of an honours physics course. It will also be of interest to industrial workers who wish to revise or clarify their basic ideas on electron devices.

M. R. GAVIN.

MODERN NETWORK ANALYSIS

By F. M. Reza and S. Seely

London : McGraw-Hill Publishing Company, Ltd. Pp. x+373. Price 77s. 6d.

In planning the contents of this book, the authors set as their goal a text that would provide the student with a broad understanding of modern network analysis at a modest level of sophistication. It would be suitable for a first graduate course or an advanced undergraduate course in which fairly general ideas are introduced.

The book is arranged in three parts. Part 1 — Fundamentals of Network Analysis, starting from the basic network elements, goes on to discuss what is meant by a linear system and defines the System Function with which the rest of the book is largely concerned. The system function T(s) denotes the ratio of the steady state output to input for an exponential excitation containing the time factor e^{st} with $s=\sigma+j\omega$. Thus the system function may be an impedance or admittance or transfer function according to circumstances.

Part 1 continues with chapters on poles and zeros on the s plane, matrices and determinants, network topology, in which the relevant properties of linear graphs are discussed, and finishes with the derivation in matrix form of the general network equilibrium equations on both loop and node bases.

Part 2 applies these ideas to two and four terminal networks. Image parameters are discussed, together with the principles of filters, without going into great detail which would constitute too specialized an application for a general text.

This section concludes with a chapter on distributed parameters and the transmission line equations.

Part 3 takes up more general topics again. Two chapters develop the properties of the system function and its use in determining the transient response and the response of the system to "Singularlty Functions," i.e. step and impulse functions. It is no doubt valuable for the serious mathematical student to appreciate that the results of these two chapters can be obtained and systematized in terms of the system function without using the Laplace Transform. One feels, however, that for the majority of students of electrical engineering it would have been more economical of effort for the student if the following chapter on the Laplace Transform had been placed earlier and its results used from the start in dealing with transients and step and impulse function inputs.

The last two chapters treat normal modes of linear systems and general properties of network functions, respectively.

This book is well conceived and on the whole well executed, though the susceptible reader may be irritated by the occasional grammatical lapses and awkward choice of words as when we are told, (p. 219), that "a simple passive network may be extremely complicated." —The writer found (E_2/E_1) $(j\omega)$ for the ratio of two functions of $j\omega$ a little difficult to stomach.

The last chapter commences by recalling the loop equations in the general form allowing current generators as well as potential generators. With e_{li} denoting the net-equivalent-potential source feeding the ith loop it states that "if the quantities e_{li} are interpreted as actual sources acting in the links of the network, and if the loop currents are regarded as actual currents in these same links, then the total instantaneous power p supplied to the network by the sources will be

$$p=e_{l1}i_1+e_{l2}i_2+\ \ldots\ +e_{ll}i_l."$$

(In passing the reader will note the rather unsatisfactory use of each of the letters l and i with two different meanings).

The hesitant form of this statement reflects a doubt about the standing of this power equation which seems to be rather widespread. In fact, if potential generators alone are present, it is easily shown to be correct however the generators are distributed round the loops, and is merely an expression of the principle of superposition. On the other hand the simplest example will show that it is incorrect if generators of both types are present. A similar statement applies to the corresponding equation for node analysis.

The main concern of this chapter is to establish properties of driving point impedance and admittance functions by use of the network energy functions. All that was actually required was a single potential generator in branch 1, with the loops chosen so that branch 1 belonged to loop 1 only, and it would follow immediately that $e_{l1}i_1$ gave the instantaneous power.

Whether because it is numbered 13, or because the authors were by this time wearying of their task, this last chapter is full of misprints as well as actual errors. In one example which purports to calculate an impedance, the fact that the method actually gives the admittance is not revealed because the numerical values have been simplified to give a result $1+0j$.

However, with reservations regarding the last chapter, this book is a useful addition to the literature on electrical

networks and a new edition should soon give the opportunity to correct some of the faults.

A. W. GILLIES.

THE ELECTRIC ARC

By J. M. Somerville

London : Methuen & Co. Ltd. Pp. ix + 150. Price 12s. 6d.

The literature on arc discharges is notoriously scanty in spite of the fundamental and technical interest in such work. Apart from some excellent publications in German there are virtually no comprehensive publications on the subject. The present book is brief but stimulating and could perhaps be described as a grace before meat.

The book is divided broadly into two parts, i.e. the stable arc and later in the book the approach to the stable arc through the spark channel, glow to arc transitions, etc. The latter part could perhaps more conveniently have come first. The work on spark channels is authoritative, as would be expected from the author's reputation in this field, and most interesting, especially to the present reviewer, although it could have been shortened perhaps in favour of more material strictly on the arc, for example on the Robson-Von Engel theory of cathode mechanisms to which only a paragraph is devoted. Again even in the restricted compass of a necessarily small book a little more could have been given on the relation between excitation and electron temperatures in arcs. These are minor matters and the author is certainly to be congratulated on his knowledge and use of the latest literature on a subject (gaseous discharges) which is now perhaps regaining some of the intrinsic attraction it had for physicists and engineers and which it should never have lost.

The book has been eagerly read in at least one laboratory working in this field and it has emerged practically unscathed from this treatment. It appears to be notably free from errors, typographical and otherwise, and is to be recommended most highly. It will be absolutely invaluable for example to undergraduate students taking courses in discharges in gases and to research students beginning work in the subject.

J. D. CRAGGS.

ELEMENTARE MECHANIK VOM HÖHEREN STANDPUNKT

By Ludwig Föppl

Munich : R. Oldenbourg Verlag. Pp. 174. Price DM 20.

This book gives an interesting, if rather brief, account of the historical development of the fundamental concepts of mechanics. The treatment centres round the personalities who were responsible for the main developments.

Archimedes, with the principle of the lever, is chosen as the first to make any significant contribution to the theory of mechanics. We then jump to the 16th century with Simon Stevin, Galileo Galilei, and the beginnings of dynamics.

The work of Galilei was carried forward by his students, notably Torricelli, and is associated with the development of the concept of force. The story continues with Kepler and Huyghens who may be said to have perfected the concept of force, and prepared the way for Newton, who added the concept of mass and formulated the laws of motion.

A long chapter, devoted mainly to Newton, ends with reference to the work of the Bernoullis and Euler in evaluating the consequences of Newton's laws.

The next chapter, devoted to d'Alembert's principle, virtual work and Gauss' principle of least constraint, is followed by one on integral principles and Lagrange's equations, and a final chapter on relativity theory.

Biographical sketches of the principal figures add to the interest of the book, which includes eight full page portraits.

Had the author been content with a less challenging title one would have nothing but praise for his book. His choice, however, invites comparison with Felix Klein's great book, and it must be said that the present book does not stand up to the comparison. The title is not in fact very appropriate, and the later chapters might be more appropriately described as advanced mechanics from an elementary standpoint.

A. W. GILLIES.

INTEGRAL EQUATIONS

By F. Smithies

London : Cambridge University Press. Pp. x + 172. Price 27s. 6d.

This is a first-class book written by an author who has himself made important contributions to the subject. It is written with remarkable clarity and economy, the arrangement of the material is excellent and the whole work is a model of careful presentation.

The amount of previous knowledge required of the reader is familiarity with the Lebesgue integral which is used throughout the book. Such knowledge would be possessed, for example, by anyone who has read the Cambridge Tract *The Lebesgue Integral* by J. C. Burkill. With this initial condition the book could fairly be claimed to be self-contained. The reader will find here a concise account of non-singular linear integral equations of the second kind, that is, those of the type

$$x(s) = y(s) + \lambda \int_a^b K(s, t)\, x(t)\, dt, \quad (a \leqslant s \leqslant b),$$

$x(s)$ being the unknown function, λ a parameter and $y(s)$ and the kernel $K(s, t)$ known functions. A detailed discussion is given for kernels which are functions of integrable square (L^2 functions), but results are also given for continuous kernels, which are treated separately when there is an essential difference between the two cases.

The introductory chapter includes a section on the Volterra equation (where the upper limit of integration b is replaced by s) which is equivalent to a differential equation with given boundary conditions. This is followed by a chapter on the resolvent kernel and the Neumann series. The theorems (known as determinant-free) which are analogous to those of the theory of systems of linear algebraic equations are derived in the

third chapter. The method of this chapter can in certain cases be used for the numerical solution of integral equations. After a discussion of orthonormal systems of functions in the fourth chapter, the classical Fredholm theory, with explicit formulae for solutions, is given in the next two chapters, the L^2 case and the continuous case being treated separately. The remaining two chapters deal with Hermitian kernels and singular functions and singular values. Linear integral equations of the first kind (those in which the unknown function appears only under the integral sign) are briefly mentioned in the last chapter.

Integral equations are of interest in physics in, among other things, potential theory and vibration problems. The mathematical physicist interested in applications will have to consult other literature but he will be helped to do so by the basic and mathematically satisfactory account given in this book.

M. R. Hopkins.

THE STRUCTURE OF METALS

London : Iliffe & Sons Ltd., published for The Institution of Metallurgists. Pp. vi + 118. Price 25s.

The authors of the four papers published in this little book are to be congratulated on having presented, in a concise and very readable form, an excellent review of modern ideas about the structure of metals. The lectures were originally given at a refresher course arranged by the Institution of Metallurgists for its members, and the wider publication is to be welcomed. In the first paper Professor Raynor summarizes in a concise manner developments during the past twenty years in the electron theory of metals, and points to some of the problems and difficulties in attempting at the present time a more quantitative application of theory to interpreting the behaviour of metals. The second and complementary paper by Dr. Catterall presents the experimental aspects of the subject and describes some of the techniques that are being used to test the theories. After outlining briefly some of the physical properties that can give useful information, he shows how their measurement can be applied to determining such factors as the width of the valence band, the shape of the density-of-states curve, the shape of the Fermi surface and the nature of charge carriers in electrical conduction. The paper concludes with a discussion of the modifications in electron structure that occur in alloys, including those of non-transition and transition elements.

The third paper, by Professor Quarrell, gives an up-to-date account of dislocation theory and of its successful application in explaining the mechanisms of deformation in metals and the effects of foreign atoms and defects on mechanical properties. One of the striking features of dislocation theory is that it developed so far before techniques were available for direct experimental confirmation and observation of the phenomena postulated. The converging evidence revealed by chemical means, such as the examination of etch pits and precipitate phases, and by X-ray studies of local changes in lattice orientation, is outlined in the final paper by Dr. Nutting. He concludes with a brief account of the recent and beautiful experiments, pioneered by Hirsch at Cambridge, in which dislocations have been directly observed and their behaviour studied in thin foils by electron transmission in the electron microscope. The reproduction of the plates in this paper is excellent and it is rather unfortunate that the numbers given to the plates do not agree with the references in the text.

Within the compass of one hundred pages, one would not expect to find an exhaustive survey of the structure of metals ; but the masterly way in which the subject matter has been compressed in this publication provides a model which many writers of modern textbooks might follow. There are useful references to the more important recent papers at the end of each chapter.

G. W. Warren.

ASTROPHYSIQUE GÉNÉRALE

By J. C. Pecker and E. Schatzman

Paris : Masson et Cie. Pp. x + 756. Price 1300 F.

This massive and encyclopedic work reminds us that the skill at reducing a whole science to a single volume is not exclusively German, and that in fact the French unique genius for clear exposition is not confined to mathematics. But of course the disadvantage is that most topics are inevitably reduced to brief summaries, and the book cannot offer very attractive continuous reading. As a work of reference it is invaluable, especially for finding connections and cross-references between conventionally separated branches of astrophysics. Thermodynamic and hydrodynamic foundations, wave mechanics of spectra, statistics, occupy the first 100 pp., and a shrewd critical survey of observational techniques fills the next 150 pp. Stellar and interstellar physics occupy most of the book, with an excellent but very brief final section on solar-terrestial effects and cometary and planetary phenomena.

Martin Johnson.

THE REALM OF THE NEBULAE

By Edwin Hubble

New York : Dover Publications, Inc. Pp. xiv + 207. Price $1·50.

Dover Publications are to be thanked for this reprint of one of the great classics of modern astrophysics. To-day when " expansion of the universe " too easily becomes taken for granted by physicists and even by philosophers, it is important to reread the careful and soberly critical work of the pioneer in actual measurement. It is worth remembering that Dr. Hubble used to be very insistent in conversation that his measurements yield " red shifts " and that to talk about them in any other terms is to step into speculations which may or may not endure. For the present reprint Dr. Allan Sandage adds a valuable assessment of the subsequent development of the subject, mentioning especially the modification of distance scale for external galaxies due to discovery of the second " population " of pulsating stars.

Martin Johnson.

THEORIES OF FIGURES OF CELESTIAL BODIES

By Wenceslas S. Jardetzky

New York and London : Interscience Publishers. Pp. xi + 186. Price 45s.

The problem discussed in this book is of considerable interest, in that it has over a long period presented a challenge to our understanding of one of the most readily observable properties of the physical universe. It is that of the shapes of the rotating gravitating masses which are the heavenly bodies. The problem has engaged the attention of many great mathematicians, astronomers and physicists. As Professor Struve points out in the foreword, the author of this book who has himself contributed to the subject, had an interesting personal link with one of them, Liapounov.

The book is divided into two parts, the first, consisting of six chapters, dealing with the theory of figures of equilibrium of a fluid mass in rotation. The mathematical treatment is thorough and important results are obtained. The methods are those associated with the names of Poincaré, Liapounov, Lichtenstein and Wavre. In the second part of the book there are five chapters which are devoted to zonal rotation, varying figures, systems composed of fluid and rigid parts, fluid mass and centres of attraction and figures of compressible masses. In this part, the models are closer to reality and the mathematical handling of them correspondingly more difficult.

A good account is given of recent work and there is a useful bibliography, and the book should be of value to those who are interested in the theories of the figures of celestial bodies and to those who intend to work on some of the unsolved problems.

M. R. Hopkins.

PHYSICS OF THE ATOM

By M. Russell Wehr and James A. Richards

London : Pergamon Press Ltd. Pp. xi + 420. Price 49s.

According to the preface " the book is designed for a one-term-course in either a liberal arts or an engineering curriculum," but in fact it covers most of the basic ideas which are likely to occur in any university " modern physics " course, although honours students would need to read up a good deal of detail elsewhere.

The authors' style is most attractive. Extensive use is made of analogies, generally helpful, in discussing difficult ideas, and clear diagrams support the text. Another pleasant feature is the care with which the reader is taken through the sequence of argument used to interpret fundamental experiments so that the increasingly complex ideas necessary for this seem inevitable and reasonable.

Two features about which opinion may be divided should be mentioned. The first is the use of the rationalized M.K.S. system of units, which simplifies discussion of " deflection " experiments but scarcely affects any other part of the book. Students should have little difficulty in modifying the few expressions which would differ in an unrationalized system. The second feature is the extensive discussion of nuclear reactors (33 pages), presumably at the expense of other topics, such as thermionic emission (half a page). The limited treatment of the latter topic is the more surprising since the welcome chapter on " the atomic view of solids " concludes with several pages of discussion of semi-conductor rectifiers and transistors.

The authors have succeeded in their aim of providing many problems which " require thoughtful analysis " and have generally avoided the common fault with this type of question that, bearing in mind the average student's background, they could only be answered by a genius.

As a final comment, the reviewer feels that the " end " of the book is unduly long. It includes an historical summary and list of Nobel Prize Winners, but there is no doubt some advantage in the provision of fairly comprehensive tables from which the student must extract his own data in working problems.

R. W. Whorlow.

THE ELEMENTS OF DETERMINANTS, MATRICES, AND TENSORS FOR ENGINEERS

By S. Austen Stigant

London : Macdonald & Co. (Publishers) Ltd. Pp. xi + 433. Price 60s.

In writing this book the author had National Certificate students particularly in mind where determinants would be studied in the ordinary course, the matrices in the higher course and tensors in an endorsement course. This intention would have been better served if the hundred pages on each of determinants and matrices were reduced to about twenty. As it is, the student could read through these two sections and be completely unaware of the reasons for studying the subject matter as all the examples are of a purely mathematical nature and not associated with any practical application. The student would also be left with the impression that the best method of solving simultaneous equations is by means of determinants.

The author presents in the third part of the book a useful account of the way the tensor rotation can be successfully applied to circuit analysis as developed by Kron. This is the most valuable part of the book as the reviewer knows of no other account in book form published in this country.

It is difficult to imagine students buying this book for themselves at this price.

C. Ritchie.

HYPERSTATIC STRUCTURES

By J. A. L. Matheson

London: Butterworths Scientific Publications. Pp. xv + 467. Price 90s.

This book is an attempt, a highly successful attempt, to survey the methods of analysis of statically indeterminate engineering structures and to demonstrate the relations between a number of well-known theorems of the Theory of Structures. Each of the main methods of elastic analysis is discussed in detail and chapters by Dr. N. W. Murray on elastic stability and by Dr. R. K.

Livesley on methods of structural analysis employing a digital computer enhance the value of this important addition to the literature of the Theory of Engineering Structures.

E. K. FRANKL.

THEORETICAL ELASTICITY AND PLASTICITY FOR ENGINEERS

By D. E. R. Godfrey

London: Thames & Hudson Ltd. Pp. x+311. Price 42s.

The author of this book is the Head of the Mathematics Department of the Woolwich Polytechnic, and the book is intended to provide a basis for further study by graduate engineers working in this field. Eight of the twelve chapters deal mainly with problems of elasticity, while the last four chapters are devoted to plasticity.

The ground covered by the sections of the book dealing with elasticity is necessarily similar to that of other textbooks covering this field; but a graduate student working by himself will probably find the book under review easier to read and to work through than some of the classical treatises. Such readers will find the appendices containing notes on the mathematical methods employed in the book, as well as a selection of fully worked problems, particularly helpful.

E. K. FRANKL.

AN ELEMENTARY TREATISE ON FOURIER'S SERIES

By William Elwood Byerly

New York : Dover Publications Inc. Pp. ix+287. Price 14s.

Byerly's treatise on Fourier's Series, first published in 1893, was used by students thirty or forty years ago when American books did not come to this country in the numbers they do to-day. Now it appears, in unabridged form, amongst the flood of Dover Editions. One wonders how much it has been used in America in the interval. It has been replaced here by more recent writings. Nevertheless, it is a lucid elementary account of Fourier's Series and of the solutions of physical problems in which these series occur. It, therefore, includes chapters on zonal harmonics, spherical harmonics and Bessel functions, which still could serve as a useful introduction to this branch of mathematical physics. There are also good collections of examples.

J. TOPPING.

A SIMPLE APPROACH TO ELECTRONIC COMPUTERS

By E. H. W. Hersee

Glasgow : Blackie & Son Ltd. Pp. viii+104. Price 12s. 6d.

A great attraction of this book is its compactness. The temptation to read it at a single sitting is almost irresistible. Only rarely is an author as successful as Mr. Hersee in achieving his aim, in this case to present in some detail as simply as possible some of the basic working principles of both digital and analogue machines. No specialist knowledge is assumed and the book is suitable for anyone from sixth-form level onwards who wants to know how a computer works. Seventy six pages are devoted to high-speed digital computers and thirty four to electronic analogue machines and simulators. An introductory chapter is followed by an account of number representation. Then come descriptions of some basic circuits used in digital computers and of the different types of memory. Programming the machine is considered at some length and illustrated by a simple example. The same pattern is followed in dealing with analogue computers. There is no reference to specific machines but just sufficient detail is given to enable the reader to get a glimpse of the basic principles. Many lecturers and teachers confronted with the task of introducing computer design and programming into undergraduate or diploma courses will welcome this excellent text.

J. CRANK.

A COURSE IN MATHEMATICAL ANALYSIS

By Edouard Goursat

New York : Dover Publications Inc. Volume I—Applications to Geometry, Expansion in Series, Definite Integrals, Derivatives and Differentials. Pp. viii+548. Price $2.25. Volume II, part one—Functions of a Complex Variable. Pp. x+259. Price $1.65. Volume II, part two—Differential Equations. Pp. viii+300. Price $1.65.

It is not easy to write anything original about books which are already so well-known and established as these by Edouard Goursat. They form a welcome addition to the Dover series of books on mathematics. They are attractively printed on paper which is guaranteed not to discolour or become brittle with age, and of the binding, it is said that the pages do not drop out. This is more than can be said of many more expensive books.

These new editions are unabridged and unaltered publications of the original translations by Hedrich and Dunkel. They are sure to be well received at such low prices.

J. CRANK.

ON MATHEMATICS AND MATHEMATICIANS

By Robert Edouard Moritz

New York : Dover Publications Inc. Pp. vii+410. Price 16s.

Here are over a thousand quotations from some three hundred authors on every aspect of mathematics. The compilation was made before 1913, so modern authors are not represented, but it is amusing and often instructive to dip in at random and note which opinions have stood the test of time.

As an epilogue to the Institute's Report on the Teaching of Mathematics to Physicists, we might quote the following :

" The advance in our knowledge of physics is largely due to the application to it of mathematics, and every year it becomes more difficult for an experimenter to

make any mark in the subject unless he is also a mathematician."—BALL, W. W. R.

" It is remarkable that a science (probabilities) which began with the consideration of games of chance, should have become the most important object of human knowledge."—LAPLACE.

" The proof of self-evident propositions may seem, to the uninitiated, a somewhat frivolous occupation. To this we might reply that it is often by no means self-evident that one obvious proposition follows from another obvious proposition ; so that we are really discovering new truths when we prove what is evident by a method which is not evident. But a more interesting retort is, that since people have tried to prove obvious propositions, they have found that many of them are false. Self-evidence is often a mere will-o'-the-wisp, which is sure to lead us astray if we take it as our guide."—RUSSELL, BERTRAND.

J. TOPPING.

AN INTRODUCTION TO THE THEORY OF GROUPS

By P. S. Alexandroff

Translated by Hazel Perfect and G. M. Petersen

London and Glasgow: Blackie & Son, Ltd. Pp. x+112. Price 17s. 6d.

This book, by a distinguished Russian mathematician, was published in Russian in 1951 and translated into German in 1954. The present volume is translated from the German. The purpose of the book is to provide an introduction to the main ideas of group theory suitable for the pupils of the sixth forms of grammar schools.

Mathematical teaching has long been handicapped by the gulf that exists between school mathematics and the kind of mathematics that is the serious and absorbing preoccupation of working mathematicians and scientists. The consequences of this are twofold. Educated people whose mathematical studies have ceased at school level have a very inadequate idea of what mathematics is about. Secondly, able pupils at school are often afflicted with a distaste for mathematics which they would not have acquired if they had been introduced to important ideas at an earlier stage. The theory of groups is a subject which is particularly suitable for bridging the gap between elementary and advanced mathematics. It can be taught *ab initio* without previous knowledge. The emphasis is on ideas rather than on mechanical drilling in computational techniques. It is a satisfactory study from the aesthetic point of view, for it includes the discussion of symmetry, which is a fundamental concept in the study of natural phenomena as well as in mathematics. Group theory contains ideas which are basic in algebra and in analysis and it has important applications in physics, for example in crystal structure and in quantum mechanics.

This introduction to the theory of groups is to be warmly welcomed. The treatment is clear and rigorous and the exposition is careful and detailed. The translators, who have added some exercises at the end of each chapter and also some references for English-speaking readers are to be congratulated on an excellent piece of work. The book will be useful, not only to pupils at school and to teachers but to many other interested readers.

M. R. HOPKINS.

OUT OF THE SKY — AN INTRODUCTION TO METEORITICS

By H. H. Nininger

New York : Dover Publications Inc. Pp. viii+336. Price $1·85.

This somewhat ambiguous title covers a very readable book on meteorites, written by an enthusiast. As Director of an important museum, the author naturally has in mind an extension of the normal guide to a great collection, with all relevant information as to chemical and physical properties. But the work is not just a guide to specimens ; the problem of atmospheric travel of meteors and their orbits is briefly treated, and the craters they make on the earth (and controversially on the moon) are discussed fully. There are valuable pointers to the share which various branches of physics, chemistry, geology, and astronomy must undertake, to ensure the growth of " meteoritics " eagerly called for by the author.

MARTIN JOHNSON.

Letters to the Editor

Teaching elementary optics

Why do so many authors of textbooks of elementary physics perpetuate the fallacy that there is a principal axis to a spherical mirror ? No line drawn through the centre of curvature enjoys any optical preference over any other, but every textbook that I have read covering the G.C.E. " O " and "A" level syllabuses defines a principal axis as one passing through the centre of curvature and the centre of the mirror.

Now it is perfectly obvious that the centre of the mirror is of no optical significance whatever and loses even any geometrical significance if the mirror isn't circular ! Any line through the centre of curvature is as good an axis as any other and the midpoint of such a line is as good a focus as any other. Surely all the authors of best-selling " O " and "A" level textbooks know this.

The matter is not without importance. That spherical mirrors, as distinct from paraboloids, have no principal axis is made use of in the design of large-field telescopes for use in conjunction with paraboloidal reflectors whose field is limited by coma. Why then do we persist in this fallacy ?

One answer which we will of course dismiss is that authors of textbooks simply copy from each other. More probably it is to secure a similar treatment for mirrors and lenses which do have a principal axis. Expediency cannot however justify a completely meaningless exposition.

G. F. Filbey (*Associate*).

Borough Polytechnic, London.

The Graduateship examination

The impression given by the " Comments of the Examiners" on the above examination, published in the September 1959 issue of the *Bulletin*, is that for a satisfactory answer to an examination question, the candidate would require knowledge of classical physics obtained from a modern textbook supplemented by a knowledge of contemporary physics.

As candidates for the above examination we would appreciate suggestions for further reading on subjects covered by the syllabus ; whilst realizing that this is a difficult problem perhaps the examiners could make suggestions covering their subjects.

Our general opinion of the comments passed by the examiners is that they are adequate as an indication to a casual reader, of the manner in which the candidates answered, or failed to answer, the examination papers, but are totally inadequate to the candidate himself. Many of the comments give no indication of the type of answer required by the examiner or the mistakes made by the students. To emphasize the difference can we refer to the comment given by Professor Lipson on Question 3 of the 1959 Physics 2 paper in the September and October editions of the *Bulletin*. The student's examination marks are not disclosed, so that he has little indication of his performance in the examination : would it not be possible to arrange for the examiners to give a more detailed analysis on the lines of Professor Lipson's comments in the October edition of the *Bulletin* for issue to students who have taken the examination ? This would also be invaluable to college lecturers.

John R. Powell
on behalf of the Grad.Inst.P. Class.

Liverpool College of Technology

Professor Craggs replies :—

One of the more unusual aspects of the Graduateship examination is the full publication and discussion of the papers in the *Bulletin*. Amongst other things this means that the examiners, of whom I happen to be one at the present time, are exposed to the full blast (sometimes hot, sometimes cold but hardly ever like a gentle spring breeze) of public opinion.

We accept this, of course, but I for one would be reluctant to analyse or to comment on the syllabuses, examination papers and scripts to any great extent, to say the least of it, as Mr. Powell invites us to do.

This does not mean that I do not sympathise with candidates, many of whom work in difficult conditions. It is not easy for the examiners to set fair papers, or for the teachers in the wide variety of establishments involved to provide an adequate balanced course covering the wide syllabus, because the colleges vary in size and in their facilities. In my opinion, however, making due allowance for the difficulties, there is little doubt that the average candidate simply does not have anything like as wide and as deep a knowledge of physics as I should expect for the Graduateship qualification. This may be that there is little time for reading or that, even, the average student is not interested in reading and relies solely on lecture material, some of which may be unsatisfactory. At any rate I doubt if a little extra help from the examiners would solve this problem. May I suggest, with all due respect, that Mr. Powell takes an undesirably utilitarian view of his course ?

I would like to comment in detail on some of the points in Mr. Powell's letter.

(i) Of course I expect candidates to have a sound knowledge of classical and modern physics, especially of the newer work on classical physics (to give popular examples I mean satellite motion, the structure of the earth, etc., etc.).

(ii) Reading should be set by the teachers.

(iii) The only type of answer I require is a good one.

(iv) The disclosure in detail or otherwise of students' marks and mistakes, etc., is I think inadvisable for various reasons. For example, I would not like to be the cause of heart failure nor, frankly, could I face the vast correspondence that would probably ensue. Indeed, there may be a case for not publishing examiners' comments at all.

(v) Finally, it would be impertinent and also highly undesirable for the examiners to presume to advise on the lecturers' work.

The above opinions are of course my own. I wish to add that the examiners and the officers of the Institute are naturally very concerned to ensure that the Graduateship examinations continue to be of a high standard and that the syllabuses, etc., provided are as carefully drawn up and as helpful as possible to teachers and candidates.

Forthcoming Institute Meetings

Date	*Place*	*Speaker*	*Title*	*Time*	*Branch or Group*
Mar. 15	**Newcastle-upon-Tyne** King's College	Dr. D. A. Wright, F.Inst.P. (*G.E.C. Research Laboratories*)	**Applications of thermo-electricity**	6.15 p.m.	North-Eastern
Mar. 17	**London** The Institute's House	Dr. F. P. Bowden, C.B.E., F.Inst.P., F.R.S.	**The friction and deformation of solids at very high speed**	6.00 p.m.	London and Home Counties
Mar. 18	**Bristol** The University	Mr. H. L. Green, F.Inst.P. (*Chemical Defence Experimental Establishment, Porton*)	**Smokes and mists**	7.00 p.m.	South-Western
Mar. 18	**Cardiff** University College	Professor C. F. Powell, F.R.S. (*University of Bristol*)	**The origin of cosmic radiation**	6.15 p.m.	South Wales
Mar. 21	**Manchester** The University	Dr. L. Essen, O.B.E. (*National Physical Laboratory, Teddington*)	**Astronomical and atomic time**	7.00 p.m.	Manchester and District
Mar. 21	**Edinburgh** The University	Dr. J. B. Birks, F.Inst.P. (*University of Manchester*)	**Recent developments in scintillation counting**	7.15 p.m.	Scottish
Mar. 22	**Glasgow** The University	Dr. J. B. Birks, F.Inst.P. (*University of Manchester*)	**Recent developments in scintillation counting**	7.15 p.m.	Scottish
Mar. 22	**London** The Institute's House	Mr. P. O. Hawkins (*Services Electronics Research Laboratory, Baldock*)	Group Annual General Meeting followed by a lecture on **Neutron sources**	5.30 p.m. 5.40 p.m.	Electronics
Mar. 23	**Sheffield** The University	Mr. F. I. G. Rawlins, F.Inst.P., F.R.S.E. (*The National Gallery, London*)	Branch Annual General Meeting followed by a lecture on **Physics and the fine arts**	5.00 p.m.	Yorkshire
Mar. 24	**Nuneaton**		Visit to Motor Industry Research Association, Lindley The number for this visit is limited and further details and application forms will be sent to Midland Branch members.		Midland
April 6 to 8	**Nottingham** The University		Conference on **Solid state microwave amplifiers** Registration is necessary. Full details may be obtained from the Secretary of the Institute.		Electronics jointly with Radio Spectroscopy
April 7	**Liverpool** The University	Mr. C. W. Oatley (*University of Cambridge*)	Symposium on **New techniques in electron and x-ray microscopy**	7.00 p.m.	Liverpool and North Wales
April 8	**London** The Institute's House		Symposium on **Source units for spectrochemical analysis**	2.15 p.m.	Applied Spectroscopy
April 8	**London** The Institute's House	Mr. R. S. Sharpe, A.Inst.P. (*Atomic Energy Research Establishment, Harwell*)	**Nuclear fuel element inspection**	6.00 p.m.	Non-Destructive Testing
April 8 and 9	**Reading** The University		Group Annual General Meeting and Spring Conference on **The borders of X-ray analysis** Registration is necessary. Full details may be obtained from the Secretary of the Institute.		X-Ray Analysis

Date	*Place*	*Speaker*	*Title*	*Time*	*Branch or Group*
April 11 to 13	**Keele** University College of North Staffordshire		Annual Conference The papers will mainly be on stress and strain measurements on fibres (both polymers and glass) Registration is necessary. Full details may be obtained from the Secretary of the Institute.		Stress Analysis
April 12	**Leatherhead** The Electrical Research Association	Mr. C. G. Garton, F.Inst.P. (*Electrical Research Association, Leatherhead*)	Visit to the laboratories of the Association followed by a lecture on **Physics of insulation**	to be announced	London and Home Counties

Admission by ticket only on application to the Secretary of the Institute.
Further details and application forms will be sent to members of the Branch.

The Institute's Journals

PRINCIPAL CONTENTS OF THE MARCH, 1960, ISSUES

Journal of Scientific Instruments : Volume 37, No. 3

Simple dosage meter for high-intensity thermal radiation. By P. H. Thomas and P. G. Smith.
A simple radiation dosage meter which uses the melting of a temperature-sensitive paint as an indicator is described. Calibration curves are given for two versions, one suitable for 5-18 cal cm^{-2}, the other for 16-60 cal cm^{-2}. An approximate theoretical analysis is also given.

Design of a single electrode capacitor for use with moisture meters and similar apparatus. By D. F. Leach, Grad.Inst.P., and J. M. M. Neilson.
Measurements of the capacitance of a single cylindrical electrode in air have been made for each of the three variables, length, radius and height above earth. The effect of surrounding it by dielectric masses of various sizes was also investigated, and the change of capacitance with increase in dielectric volume determined. The influence of these factors when designing a capacitor of this type is discussed. This electrode has been successfully used for measuring the moisture content of textile packages, and could be used for similar applications involving measurement of dielectric properties.

Method of measuring the angular deflexion in a dynamometer. By M. Axson and J. M. Magarshack.
In the method to be described, unidirectional square-wave current pulses are produced with a mark-to-space ratio proportional to the deflexion of the spring system in a dynamometer. The pulses are fed to a moving-coil meter which has a sufficiently slow response to read the mean current. The reading is then proportional to the deflexion. Two systems for producing the square-wave pulses are discussed. The first is robust and simple in construction and can be applied when the forces to be measured are large. The second system can be used for the measurement of small forces where it is undesirable to make any physical contact with the dynamometer.

Apparatus for investigating total hemispherical emissivity. By J. H. Cairns.
An apparatus is described for measuring the total hemispherical emissivity of highly polished metals and alloys over the temperature range 100 to 900°C. The apparatus consists essentially of a highly polished, hollow, cylindrical sample supported within an evacuated enclosure of only slightly larger dimensions. Provision is made for raising the temperature of the sample above that of the enclosure by means of an internal heater contained within the hollow sample. Emissivity values are obtained by observing the rate of loss of heat from the sample after switching off the heater, and substituting this observed value in a specially derived radiation equation. An accuracy of better than $\pm 8\%$ and a reproducibility of $\pm 5\%$ are claimed for the emissivity values. Experimental data for titanium are included as an example. The apparatus is also capable of direct measurement of specific heat over the same temperature range to an accuracy of $\pm 2\%$.

Oscillator measuring equipment for vibrating-wire gauges. By W. H. Ward and J. E. Cheney.
Vibrating-wire gauges are well known for their versatility in the measurement, not only of strain, but of many other physical quantities. It has been found that for some purposes the usefulness of the gauges has been restricted by limitations in the traditional reference-wire method of measurement. The design, construction, calibration and use of a new instrument which measures the frequency of vibrating-wire gauges is presented. It utilizes a variable-frequency electronic oscillator, which is continuously checked against a tuning-fork and regularly checked by time signals. Two models of the present version of the instrument have given very satisfactory performance under difficult conditions on civil engineering projects. The new instrument is cheaper and simpler to make than the traditional type and covers a frequency range of about 250 to 2500 c/s.

Extensometer for semi-rigid materials. By C. D. Kinloch and N. E. Waters.
A differential capacitance extensometer is described which is capable of measuring extensions between 1 and 50% on an unstrained gauge length of one inch. With this instrument, complete tensile stress-strain curves to the point of rupture of the test piece may be obtained on semi-rigid materials.

Design criterion for correction of parrallax at the best focus for definition. By G. W. Hamstead, F.Inst.P.
Parallax is the angular aberration of an optical system. Conventional balance of primary against secondary aberration does not give the best definition with freedom from parallax. A design criterion is established to obtain this desirable condition and tolerances calculated.

Direct measurement of $\int i^2.dt$ by a method based on the Hall effect. By S. C. Ryder-Smith, A. E. Guile and A. E. Barrington.

A squaring unit based on the Hall effect is used to give an a.c. output, the amplitude of which is proportional to the square of an input current. The input impedance is low, so that the unit may conveniently be fed from a shunt. The output is amplified in a tuned amplifier, and fed through a rectifying circuit to an integrating instrument such as a flux-meter, so that a direct reading of $\int i^2.dt$ is obtained. A modification is suggested to enable $\int eidt$ to be measured, giving the arc energy in a circuit breaker or fuse. Thus, direct and immediate readings of these integrals can be obtained, and the need to apply time-consuming graphical techniques to records of the appropriate current or voltage waveforms is avoided. The accuracy is shown to be better than 2%.

Simple ultramicro-pipette for electron microscopy. By R. Hardy, J. R. Majer and S. Travers.

A design for an ultramicro-pipette which permits the controlled delivery of droplets down to 2μ in diameter is described. After measurement by means of a screw-micrometer eyepiece, the droplets are deposited directly upon film-covered electron-microscope grids by means of a micro-manipulator. This technique allows particle counts of suspensions of submicroscopic particles to be made with greatly increased precision.

British Journal of Applied Physics : Volume 11, No. 3

Summarized proceedings of a conference on X-ray analysis, Leeds, April 1959.

The 1959 Spring Conference of the X-ray Analysis Group of The Institute of Physics was held in the University of Leeds, on April 17 and 18, 1959. The conference was devoted to clay minerals and biological fibres and the proceedings are summarized in this Report.

Influence of instrumental aberrations on the Schultz technique for the measurement of pole figures. By B. Gale and D. Griffiths.

An experimental and theoretical investigation of the Schulz reflexion technique for measuring pole figures has shown that it is capable of giving accurate results provided the integrated intensities are measured. A detailed discussion is given of the influence of the aberrations of the optical system on the diffraction-line shapes from which it is concluded that the integrated intensities are unaffected by tilting the specimen and that, for large tilts, the vertical height of the beam is limited only by its overlap of the specimen or by lack of resolution of neighbouring diffraction lines.

Fourier series associated with duty cycles. By C. G. Mayo and J. W. Head, F.Inst.P.

An arbitrary function $F(\theta)$ of period 2π may be divided (by "time multiplex") into n parts $H_kF(\theta)$ $[k=0, 1 \ldots (n-1)]$ each of which is only different from zero for $1/n$th of the cycle [when $2k\pi/n < \theta < (2k+2)\pi/n$] and is then equal to $F(\theta)$. The Fourier series for $F(\theta)$ (in its exponential form) may also be divided (by "frequency multiplex") into n sub-series $F_u(\theta)$ $(u=0, 1 \ldots n-1)$ each of which contains only every nth term of the series for $F(\theta)$, that is to say, terms involving $\exp(sn+u)i\theta$ where s is an integer. A relation is established between the time-multiplex sub-divisions $H_kF(\theta)$ and the frequency-multiplex sub-divisions $F_u(\theta)$ and special cases are considered, namely (*a*) all the $H_kF(\theta)$ zero except one, (*b*) $F(\theta)$ constant for $1/n$th of the cycle and otherwise zero, when the behaviour of the series obtained can be checked by contour-integration methods of series summation. In case (*a*) all the $F_u(\theta)$ are equal while $F(\theta)$ is different from zero, and mutually cancel otherwise.

Inter-observer checks on standards of performance in evaluating thermal precipitator slides. By J. W. J. Fay, J. R. Ashford and P. H. Smith.

The problems associated with a monitoring procedure for maintaining satisfactory levels of counting thermal precipitator slides by members of a widely scattered team are discussed, with particular reference to the Pneumoconiosis Field Research of the National Coal Board. Experience within the research, since it started in 1953, is described and details are given of a new procedure based on a hierarchy, topped by a small number of "Master Counters," the mean of whose counting levels is taken as the standard of reference of the whole team.

The results obtained are summarized and it is concluded that the method gives an adequate measure of control. Some improvements to be applied in future checks are mentioned.

Anode surface effects in diodes containing oxide-coated cathodes. By B. J. Hopkins, A.Inst.P.

Two types of experimental tube have been built to study the behaviour of thin films deposited on the anode by evaporation during the breakdown and activation of calcium and barium oxide coated cathodes. First, with diodes of cylindrical symmetry, a contact-potential-difference method has been used to follow the changes in anode work function during activation of the cathode at several anode potentials. Emission-poisoning effects have been related to changes in the anode work function and it appears that there are two separate contaminating films on the anode surface: a very tightly held electropositive layer and a loosely bound electronegative layer. The emission decay process by the decomposition of compounds on the anode does not explain the results adequately. The second tube contained a movable glass electrode upon which a gold film could be deposited by evaporation. The results from these tubes confirmed those from the cylindrical diodes and also the validity of the contact-potential-difference method.

Purification of organic materials by zone refining. By J. H. Beynon, F.Inst.P., and R. A. Saunders, Grad.Inst.P.

Three zone refiners are described which between them are suitable for dealing with materials having melting points in the range −10 to +300°C in quantities of from 0·5 to 9000 g. Some of the more interesting results are discussed in detail, and a list of compounds which have proved amenable to this method of purification is given.

Stroboscopic radiography with a linear accelerator. By B. J. Vincent, Grad.Inst.P.

High-definition stroboscopic radiographs of an internal combustion engine have been obtained. Efficient use of the large accelerator output has enabled fine-grain film and a large film-focus distance to be used. The radiographs have been used to check the performance of the engine valves under running conditions. Comparison is made with stroboscopic radiography using a betatron. Methods of synchronization and some possible uses of stroboscopic radiography are briefly discussed.

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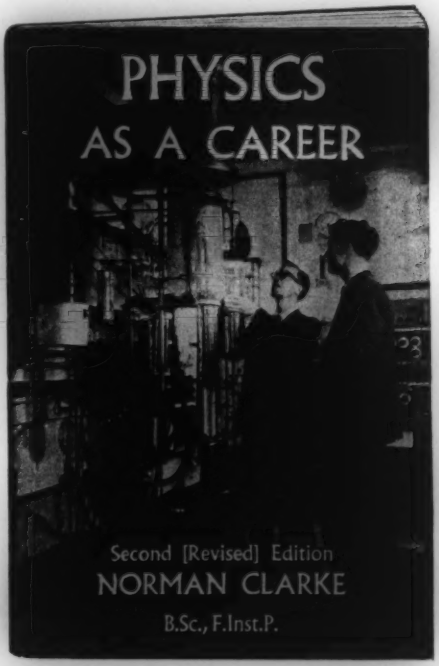

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